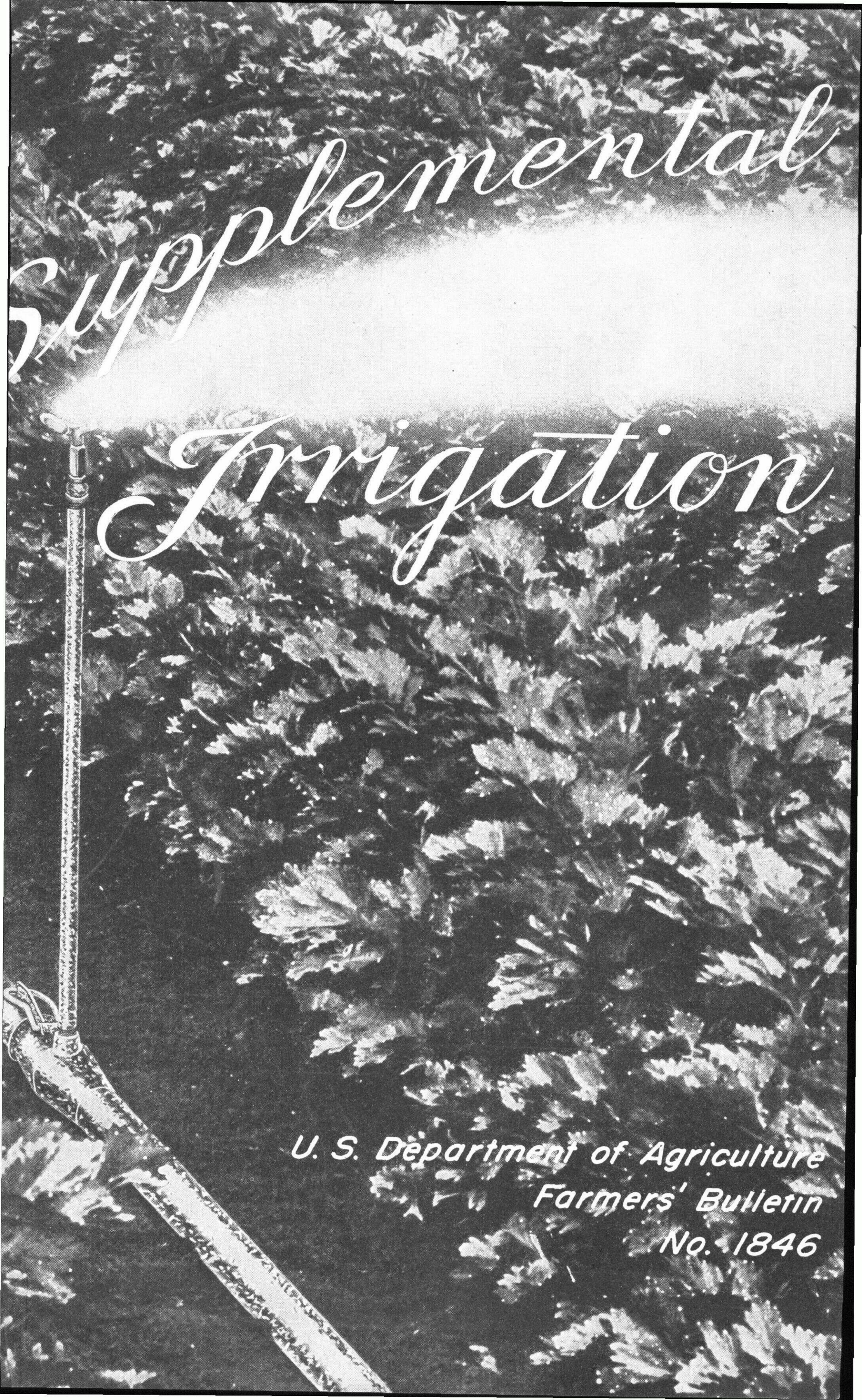
Supplemental
Irrigation
U. S. Department of Agriculture
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SUPPLEMENTAL IRRIGATION helps the farmer to carry his crops through those minor and major droughts which occur even in localities where the average annual rainfall is adequate for the production of satisfactory crops. Its use is increasing, although for financial reasons it is confined largely to the higher priced garden and orchard crops.

Sprinkling, surface irrigation, and subirrigation are all practiced, although special conditions are necessary for the latter. As the assembling of an irrigation outfit is foreign to the farmer's ordinary experience, and information on the numerous different kinds of equipment that might be used is not readily available, the most important of these are discussed in this bulletin. Because of the specific questions asked by farmers in localities where no existing irrigation outfit is available for inspection, the different types and arrangements of equipment have been discussed in detail.

This bulletin supersedes Farmers' Bulletins No. 1529, Spray Irrigation in the Eastern States, and No. 1635, Surface Irrigation in the Eastern States, and includes material on subirrigation and the new type of portable sprinkling irrigation.

Washington, D. C. Issued October 1940

SUPPLEMENTAL IRRIGATION

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Contents

INTRODUCTION

SUPPLEMENTAL IRRIGATION is the artificial watering of crops in regions where rainfall is ordinarily depended on for moisture. It is used to prevent retardation of growth during periods of drought. Although these periods may be of comparatively short duration, even a few days' check in the growth of plants may be of great importance in a short growing season.

While it is hoped that this bulletin may have a general application to the irrigation problems in any humid area in a temperate zone, it is written to apply specifically to that part of continental United States lying east of the one-hundredth meridian, that is, the area to the east of a line that would cut off the Panhandle of Oklahoma and pass through North Dakota, South Dakota, Nebraska, Kansas, and Texas.

WHY SUPPLEMENT RAINFALL?

The average annual rainfall in this region varies from approximately 20 inches along the western boundary to a maximum of more than 80 inches in a small area at the junction of Georgia, North Carolina, and South Carolina. The April-to-September precipitation ranges from about 15 to 39 inches.

[1] Now with Bureau of Plant Industry, Division of Fruit and Vegetable Crops and Diseases.

Even 20 inches of rainfall annually is probably enough to mature good yields of most crops if there is precipitation when needed and at a rate slow enough to permit the soil to absorb all the water. This, however, is not the case; the distribution of moisture is uneven over a large part of the region.

Rainfall records over a 20-year period and covering 18 localities in as many States of the humid region showed that on an average of once in 7 years there was a period of 6 weeks or longer during which not more than one-fourth inch of precipitation fell in any 24 hours. Such a period is likely to affect seriously the yield of many crops, and the frequency of such occurrences indicates the possibility of many reduced harvests.

A like period of 28 days or more occurred every 2 years. Almost all the shallow-rooted and delicate truck crops, and even such crops as potatoes, tomatoes, and lima beans, would have exhausted the moisture in the soil available to their root systems in much less than 28 days. If a dry spell occurs at an inopportune time, such as when sweet corn is in the milk stage or when lettuce is heading, the damage to the crop is likely to be serious.

IRRIGATION AS INSURANCE

Supplemental-irrigation equipment, if available, permits a farmer to water his crops when necessary to prevent serious set-backs due to lack of moisture. It also allows the farmer to moisten his land when it is too dry to plow and thus makes possible the preparation of his land for planting at any time in the summer. Both of these conditions help to stabilize crop yields and thus emphasize the insurance quality of expenditures for supplemental irrigation. In wet years the equipment may be used little if at all, but when a drought occurs it may save a crop. Supplemental irrigation is in fact best thought of and maintained as insurance against loss of crop from drought.

In the area under consideration it is estimated that of the lands with this type of insurance—supplemental-irrigation equipment—83,500 acres were devoted to the growing of truck or garden vegetables, 51,000 to orchard fruits, and nearly 200,000 to the more ordinary farm crops.

A LONG-RANGE INVESTMENT

Although many irrigation outfits have increased profits enough in the first year of operation to pay the entire cost of installation, most outfits require a number of years to recover the original investment. Climatic conditions, marketing conditions, and management are among the factors that determine the rapidity with which the installation cost is recovered. The crop or crops under irrigation, the depth of their rooting system, and the readiness with which they are damaged by drought or respond to irrigation, will also be important. Certain tracts show the effect of dry weather much more quickly than others. In wet years, however, a large investment is tied up in irrigation equipment which for that year is useless.

Because many variables are involved, it is possible usually only after a period of years to determine whether money invested in supplemental-irrigation equipment was well spent. When deciding

whether it is desirable to install an irrigation system on a certain tract, the average probable use should be carefully considered. Supplemental irrigation should be thought of as a normal farm operation. Seldom is it possible to secure and install the equipment in a short enough time to save a crop already suffering from lack of water.

The essentials of an irrigation system are a water supply, a means of putting the water in motion, a means of directing its flow, and a method of distributing it so that it may be absorbed by the plant roots.

WATER SUPPLY

In the humid area nearly every farmer who has an irrigation system has developed and now controls his own water supply and does his own pumping, if pumping is necessary. Large water-supply developments, either public or corporate, whose prime purpose is to furnish water to many farms for irrigation are not found except in the Rice Belt.

If several sources of water are available, the most dependable source should have preference. If all are equally dependable, the water supply nearest the field to be irrigated is generally to be preferred to a more distant one, as a long pipe is expensive and a long ditch, if a pipe line is not needed, is apt to be wasteful of water. In areas where good wells may be obtained cheaply a portable pumping plant and several wells in different parts of a large field may be much cheaper than a single water supply with a long pipe line.

QUALITY

The quality of water is important, although in this territory there have been few instances where water supplies were abandoned because of poor quality. Water should, first of all, be free from contamination and harmful bacteria. In general, any drinkable water is satisfactory for supplemental irrigation; a great many waters that are not drinkable, however, are used. Many so-called hard waters and many waters that contain vegetable matter are satisfactory. Vegetable matter should be strained out before the water is used for sprinkling irrigation. Some waters containing industrial wastes may be used if the foreign matter is very diluted in even extremely dry weather. It is advisable to consult the local county agent, the State agricultural college, or the Department of Agriculture, before deciding to use any questionable water. In most of the region considered it is believed that intermittent spells of heavy and protracted rainfall will leach the soil with sufficient frequency and thoroughness to prevent permanent accumulation of harmful chemical salts.

QUANTITY

The quantity of water available is a determining factor in the selection of the proper type of distribution equipment and in the rate of application. Except for basin irrigation, water must not be added faster than the soil can absorb it.

Table 1 has been prepared to indicate the quantity of water necessary to irrigate an acre of land in a specified length of time. It is

applicable to any field and any type of irrigation. From this table the number of gallons of water required per minute of continuous flow to irrigate an acre of ground to different depths may be read directly. Multiplying this number by the number of acres in the tract to be watered will determine the needed capacity of the water supply, in gallons per minute. For instance, to irrigate 1 acre to a depth of 2 inches in 60 hours—either in six 10-hour days or in five 12-hour days—requires 15.08 gallons per minute; to irrigate 10 acres to the same depth in the same time required a rate of flow 10 times as great, or 150.8 gallons per minute.

TABLE 1.—*Number of gallons of water per minute required per acre for covering tract in specified periods*

Water to be applied in—					Water applied to a depth of—					
Hours	10-hour days	12-hour days	20-hour days	24-hour days	1 inch [1]	1½ inches [2]	2 inches [3]	3 inches [4]	4 inches [5]	6 inches [6]
Number	*Number*	*Number*	*Number*	*Number*	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*
30	3				15.08	22.62	30.16	45.24	60.32	90.48
40	4				11.31	16.97	22.62	33.93	52.64	78.96
50	5				9.06	13.59	18.12	27.18	36.24	54.36
55	5½				8.23	12.35	16.46	24.69	32.92	49.38
60	6	5			7.54	11.31	15.08	22.62	30.16	45.24
66		5½			6.86	10.29	15.72	20.58	27.44	41.16
70	7		3½		6.47	9.71	12.94	19.41	25.88	38.82
80	8		4		5.66	8.49	11.32	16.98	22.64	33.96
90	9		4½		5.03	7.55	10.06	15.09	20.12	30.18
100	10		5		4.52	6.78	9.04	13.56	18.08	27.12
110			5½		4.11	6.17	8.22	12.33	16.44	24.66
120		10	6	5	3.77	5.66	7.54	11.31	15.08	22.62
140			7		3.23	4.85	6.46	9.69	12.92	19.38
160			8		2.83	4.25	5.66	8.49	11.32	16.98
180			9		2.51	3.77	5.02	7.53	10.04	15.06
200			10		2.06	3.09	4.12	6.18	8.24	12.36
240				10	1.89	2.84	3.78	5.67	7.56	11.34

[1] Suitable for sprinkling irrigation, eyelet or porous hose.
[2] Suitable for surface irrigation, heavy soil, little waste.
[3] Suitable for surface irrigation, average soil, short runs, careful handling, limited waste.
[4] Suitable for surface irrigation, average soil, average waste, some subirrigation.
[5] Suitable for surface irrigation, sandy soil, large waste, some subirrigation.
[6] Suitable for much subirrigation.

Different types of irrigation equipment require different quantities of water for their use, and further comments on needed water supply are made as types of distribution equipment are discussed.

SURFACE WATER SUPPLIES

Many lakes, ponds, and rivers are used for water supplies, and are very satisfactory if sufficient water is available. Some of the smaller ponds and streams have so little water in a drought period that it is necessary to stop or reduce irrigation just when the need is greatest. It should not be overlooked that it is during the worst droughts that water for irrigation is most needed and that high-quality produce commands the best price.

Every water supply that might be used for irrigation at some later date should be checked in periods of drought. Records of low water levels of ponds under consideration should be preserved; a permanent stake marking the water's edge in extreme drought is a convenient method.

STREAM MEASUREMENT

The actual flow of any small stream should be measured before an irrigation system dependent on its water supply is constructed. This measurement should preferably be made at extreme low-flow conditions; however, if this is not possible, ample allowance for the likely reduction in flow during long-continued drought should be made in estimating the minimum flow to be expected at a future time of need.

Sometimes it is possible to measure the rate of flow in a small stream by observing the time it takes to fill a barrel of known capacity. To do this it is necessary to deflect the entire flow of the stream through a trough, or pipe and trough system, by means of a suitable dam and to catch the water in the barrel. The system should be so arranged that the section of trough adjacent to the barrel may be moved. With the barrel empty and the outfit set up to discharge outside the barrel, everything is in readiness to make a measurement as soon as steady flow is directed through the trough. At a given instant the movable trough is deflected to discharge into the barrel and the time required to fill the barrel carefully observed, generally in seconds. The barrel should then be emptied and the measurement repeated, preferably several times, to insure reasonable accuracy.

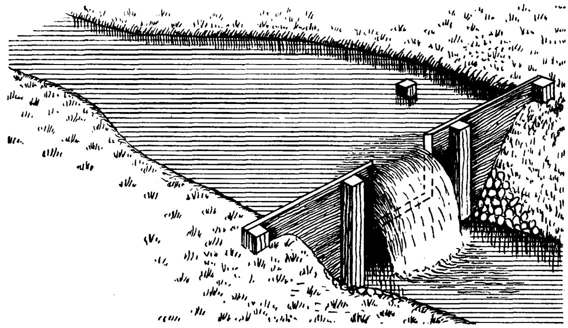

FIGURE 1.—Weir board in stream.

Where this method is not applicable and the stream has sufficient fall so that the water level on the downstream side will be below the crest of a suitably installed weir, a measurement of flow may be made with the aid of such a device. The precautions as to relative depth and length of stilling basin above the weir as indicated for a weir box in Farmers' Bulletin 1683, Measuring Water in Irrigation Channels, must be observed if accurate measurement is to be secured. The stilling basin, if it gets silted up, must be cleaned out, and sufficient time for the water level to restore itself to normal must be allowed before a measurement is undertaken. Tables showing the discharge for given depths of water flow of weirs of different lengths and of triangular V-notch weirs are included in Farmers' Bulletin 1683. If only a few measurements on a few succeeding days of extremely low-water conditions are desired, a temporary setting of a weir board (fig. 1) is often resorted to. If measurements of flow are to be made periodically over a number of months, a weir box suitably installed is to be preferred. In places where the fall in the stream does not permit accurate stream-flow measurements by means of a weir, a Parshall flume may be installed. It, too, is described in Farmers' Bulletin 1683.

UTILIZING SMALL STREAMS

It is possible to utilize some small streams by developing a storage reservoir of ample capacity at a natural widening of the channel. The storage capacity may be enlarged both by excavation and by building a dam across the stream bed to raise the water level. This is sometimes done even where it is necessary to build levees along one or both sides of the reservoir to hold the water at the higher level (fig. 2). Data on dams and levees for impounding water may be found in Farmers' Bulletin 1703, Farm Reservoirs.

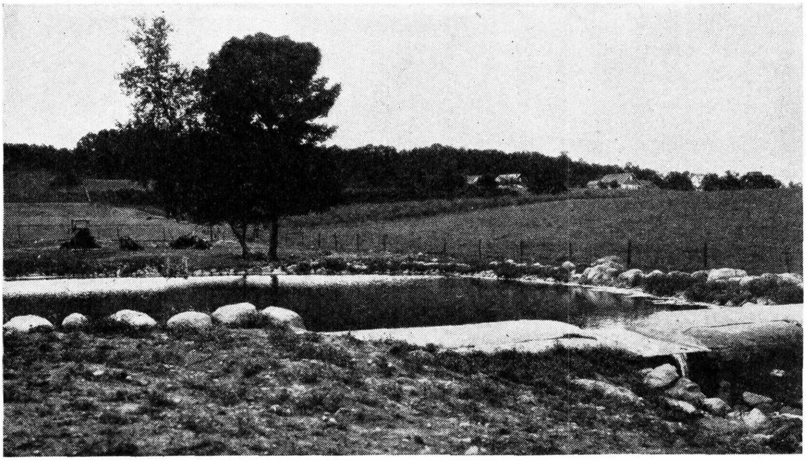

FIGURE 2.—The excavated material from the bottom of this small stream was used to build a part of the dam and a levee on one side of the reservoir.

Reservoirs of this type may be built to store the nighttime flow for daytime irrigation, or they may be built to store a season's irrigation supply. Capacity of reservoirs for a season's supply should be planned to allow for water loss due to seepage downward and outward through the soil and to evaporation from the surface. A reservoir constructed to meet both of these conditions will serve for continuous irrigation even in a protracted drought, but no intermediate basis of storage will insure water for irrigation to the end of a long drought. Spillways ample enough to pass all anticipated floodwaters without damage to dams or levees should be provided.

In some areas where the surface conditions are not favorable for the construction of one large reservoir, it is possible to construct several small reservoirs to serve the same purpose. If this is done each reservoir must have an ample spillway, and all but the downstream reservoir should be equipped with gates or pipes with valve controls set at a low elevation for drawing off the stored water.

UTILIZING FLASH-TYPE STREAMS

A stream that carries plenty of water in dry weather but whose water level is subject to violent fluctuation may be used, but adequate protection against damage at high-water stage must be provided.

A simple method, is to install a centrifugal pump permanently at a suitably low level for ordinary operation and permit it to go under

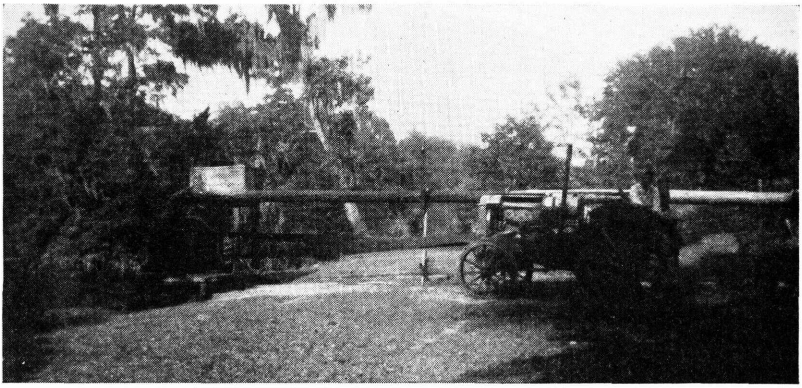

FIGURE 3.—Permanently installed centrifugal pump subject to frequent overflow. The tractor and belt are moved to higher land if flooding is indicated.

water at high-water time (fig. 3). This method is common with tractor-driven outfits using the cheaper grade of centrifugal pumps. A few high-grade centrifugal pumps are installed under similar conditions.

On many streams it is necessary to make provision to keep floodwaters from coming in contact with electric motors or engines. Motors, in particular, tend to dry out very slowly after a wetting, and damp pump houses delay the process even more. Turning the electricity on a motor with damp windings is very likely to result in burning out some coils. Wet electric motors may be dried out by blowing warm dry air through the windings by means of electric fans set behind lanterns. Many hours or even days may be required to dry wet motor windings.

Efforts to keep machinery from getting wet in floodtimes take two general directions: (1) Surrounding the machinery with impervious walls extending amply above any anticipated high-water level (fig. 4)

FIGURE 4.—Although floodwaters have risen well up its walls several times, this pump house has kept the machinery within from getting wet. Its solid walls of dense concrete extend well above any anticipated high-water level. Access to the pump house is through the roof.

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and (2) raising the machinery itself temporarily above the danger point. Machinery may be raised above flood level in several ways—such as mounting the machinery on a tractor, skid, or drag so that it may be disconnected from the piping and hauled to higher land; installing it on small cars set on sloping tracks on the stream banks so that it may be raised with a winch and cable; and hoisting it directly upwards by means of chain block equipment hung from a scaffold. Desirable arrangements differ with circumstances.

UNDERGROUND WATER SUPPLIES

Many supplemental-irrigation systems depend on underground water supplies. Wells of various types are used, extending through about all classes, including dug, driven, and bored wells; open-end cased wells; screened wells; and wells with a gravel envelope. Any type is satisfactory if it yields a dependable water supply of satisfactory quality and quantity. Small dug wells generally do not furnish enough water for irrigation. Small driven wells, 1½ and 2 inches in diameter, are used in many of the older irrigation plants. These, however, are generally used in batteries; very few are used singly even for a small irrigation outfit. Increasing use, however, is being made of 4- and 6-inch wells. Few of the drilled or bored wells flow, but many yield water freely when pumped. A new well should be thoroughly tested before it is accepted from a contractor.

MUNICIPAL WATER SUPPLIES

Municipal water supplies are excellent for irrigation but are available to relatively few farmers. Even where supply pipes of sufficient size pass near a field to be irrigated, the charge for water in irrigation quantities may be too great or the city water system may not have a capacity that warrants supplying irrigation customers. If water mains pass near the field to be irrigated, the rates should be looked into. Water for irrigation may be obtained at reduced rates from some municipal systems in return for granting a right-of-way for the pipe line that crosses the farmer's land.

LEGAL REQUIREMENTS

Until recently in the region covered by this bulletin it has generally been assumed that there was no objection to appropriating water from any available natural stream, provided the flow was not shut off from downstream owners who might use the water supply. Now, however, certain States have passed laws regulating the appropriation of water for irrigation purposes. Generally the conditions laid down for securing a permit are not onerous, but a permit is required to make the appropriation legal. Securing a permit may be a protection in subsequent years. It is, therefore, advisable to make certain whether or not there is a State law covering appropriation of water from a natural stream, open pond, or lake. Assurance on this matter can usually be secured from the State officers, the members of the agricultural engineering staff of the State agricultural colleges, or the Soil Conservation Service, United States Department of Agriculture.

SOURCE OF MOTION OR FLOW

Fortunate is the prospective irrigator who has a nearby source of gravity water, that is, water at a sufficiently high elevation to flow to his field without the aid of a pump, or in whose field there is a flowing well. The type of irrigation that may be used may be restricted, but at least there need be no operating cost for water. In general, however, the irrigator in the supplemental irrigation belt must expect to install and operate pumping machinery in order to raise the water from his source of supply and distribute it to the fields.

PUMPS

Before purchasing a pump or pumping unit, it is recommended that the farmer go to several reputable manufacturers or their representatives, state that the pump is wanted for supplemental irrigation, and furnish them with as much information about the proposed installation as possible. The pump maker must know how many gallons of water per minute will be required (table 1), and against how many feet of head (as total dynamic head) the pump must work. The head, as used in this bulletin, is the height of an equivalent column of water that would give the same pressure. With fresh water at 62° F. each foot of head is equivalent to a pressure of 0.433 pound per square inch at the base of the column. The dynamic head, in pumping, is the normal head against which the pump must work after the suction and discharge heads have become constant. If the pressure or head against which the pump must work is not known with certainty, give full information about the piping system, the water supply, the static lift, and the type of irrigation to be used. The static lift is the lift when there is no motion. The data about the piping system should include the length and size of suction pipe, the length and size of all pipe in the main transportation pipe and its branches, and data on all pipe fittings through which the water must flow in traveling from the water supply to the distribution outlets.

A knowledge of the total dynamic head against which the pump must work is essential in determining the power required to drive the pump. Total dynamic head is generally figured in feet and is made up of the following parts:

	Feet
(A) Suction lift (1, static difference in elevation from water surface to center of pump when the pump is not operating, plus 2, draw-down, plus 3, friction on the suction side)	--------
(B) Discharge head (1, static difference in elevation from center of pump to outlet, plus 2, friction on the discharge side)	--------
(C) Pressure required at the nozzle-pipe connection	--------
(D) A possible head due to difference in velocity of the water at the two sides of the pump	--------
Total dynamic head	--------

The static difference in elevation between the surface of the body of water from which the pump is drawing and the center of the pump casing, if centrifugal, or the center of the pump cylinder if displacement, is measured at a time when the pump has not been in operation for several hours. The draw-down is the difference between the level

of the water in the well when there has been no pumping for several hours and the level when pumping has been going on long enough to permit the water to become practically stationary.

If the pump draws from a large body of open water, the first item of part A, the static difference in elevation between the water surface and the center of the pump, may be readily determined by any of the means commonly used for determining differences in elevation. A surveyor's level and rod is probably the most handy. A carpenter's level, a straight edge, and a measuring stick will suit many situations. If the pump draws from a large body of open water, there will be no lowering of the water level while the pump is running; therefore, there will be no draw-down, so item 2 of part A will be zero and will drop out. Item 3 of part A, friction in the suction pipe, may be determined from the data given in table 5 or 6, depending on conditions. Item 3, will not be of great importance if a short, straight suction pipe of ample size is installed. Friction in pipes is discussed in the section on transportation. Friction in the suction pipe is similar to friction in transportation pipes.

If the pump is to draw from an open well, item 1 of part A may be determined with a float and tape. In some installations, there may be room enough outside the suction or drop pipe, or the column or eduction pipe, as the case may be, to use a float and tape. More frequently the location of the normal ground-water surface in the well may best be determined by the tire-pump and air-tube method described in Farmers' Bulletin 1404, Pumping from Wells for Irrigation.

The draw-down in some wells is very little and in some is many feet. It depends on the underground water supply and the freedom with which the water-bearing strata from which the well draws yields water.

If good information as to the draw-down to be expected in any well when a given number of gallons per minute is being pumped is not available, it is recommended that a well test be made. A well test will cost some money, but it is the only way of selecting pumping machinery that is suited to the job. If a test of the well has been made and a well chart has been prepared, as shown in Farmers' Bulletin 1404, it will not be difficult to make a reasonable estimate of the amount of item 2 of part A.

The discharge head, part B, consists of item 1, the difference in elevation between the pump and the outlet, plus item 2, the friction in the discharge pipe. For surface irrigation there is ordinarily a single and well-defined outlet and the length of the discharge pipe is definite. For most sprinkling-irrigation systems it is convenient to consider as the outlet the point where the hose or sprinkler pipe is attached. Special conditions may require that a different point be considered as the outlet. If a sprinkling-irrigation line is laid up a slope from the connection point, enough additional elevation must be allowed to provide for delivery at the highest outlet. If a surface-irrigation plant is designed to discharge simultaneously through several outlets, sufficient static head, or difference of elevation, must be allowed to provide for delivery to the highest outlet. The friction may be determined, based on carrying the full quantity to the first outlet, and a suitably lesser quantity to each subsequent one if a number of outlets will be used at any one time.

The average discharge head for the system is often useful if the system has a number of outlets or a part of the area is at a much higher elevation than the rest. Maximum head should be determined, and minimum head if it is expected that a centrifugal pump will be used.

Part C, the head or pressure to be allowed for sprinkling irrigation is discussed on pages 44–46.

Part D, the velocity head, is ordinarily negligible in farm-irrigation practice. It is probably always negligible if the sum of the other items exceeds 40 feet and pipe sizes reasonably related to the pump connection fittings are used for the suction and discharge pipes. It may be important if the sum of the other items that go to make the total dynamic head is less than 20. In case of doubt, it is suggested that the question be referred to the Department of Agriculture, or to the engineering department of one of the State agricultural colleges.

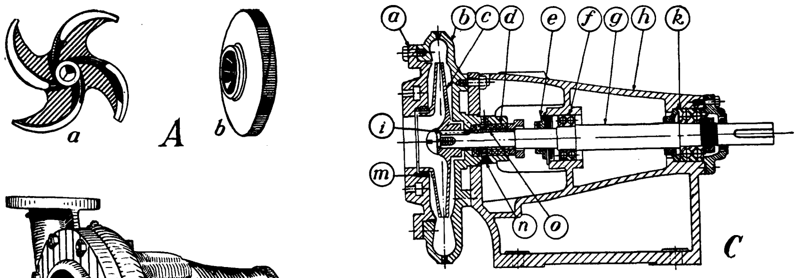
Centrifugal Pumps

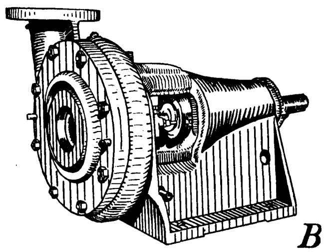
The pump most commonly used in supplemental irrigation is the horizontal centrifugal (fig. 5). It consists of an outer shell to confine the water and a rotating central member called the impeller. The impeller, mounted within the shell on a horizontal shaft, when being rotated by the shaft that passes through its center throws the water outward by centrifugal force. The shape of the casing helps to convert the energy imparted to the water by the rotating impeller into useful pressure head.

These pumps may be equipped with single suction (figs. 5, *B* and *E*), in which the suction connects with the center of the side of the pump and leads the incoming water directly to one side of the impeller, or with double suction (fig. 5, *D*), in which the incoming water is lead to both sides of the impeller. For the single-suction pumps the impellers may be open, semiopen, or enclosed. Open and enclosed impellers are illustrated in figure 5, *A*. Open-impeller single-suction pumps are the cheapest and least efficient of the group; and enclosed-impeller double-suction ones the most efficient and most expensive. All types are used, but the single-suction are most common. Owing to the relatively few hours of operation a year, the difference in efficiency is not ordinarily important. Two or more stage centrifugals are available for high heads but, owing to recent developments in single-stage pumps, are generally not needed for supplemental irrigation.

The best grades of these double-suction enclosed-impeller pumps are equipped with an outboard or pedestal bearing at each side of the pump chamber for direct connection with the driving unit. If intended for belt drive (fig. 5, *D*), the best grades will be mounted on a sub-base and provided with a third pedestal bearing to support the shaft at the outer side of the pulley. In some pumps even a fourth pedestal bearing will be provided to support the shaft on the inside of the pulley, thus removing from the pump casing any strain due to the tension of the belt.

The cheaper grades of pumps are provided with less expensive supporting arrangements. Under any circumstance a pump with substantial bearings is desirable. Where electric drive may be used, the so-called close-coupled or built-together pump gives a cheap and compact unit in small sizes (fig. 5, *E*).





NO.	NAME OF PART	NO.	NAME OF PART
a	SUCTION COVER	*g*	PUMP SHAFT
b	PUMP CASE	*h*	SUPPORTING FRAME
c	IMPELLER	*i*	KEY
d	PACKING RINGS	*k*	THRUST BALL BEARING
e	WATER SLINGER	*m*	WEARING RING
f	RADIAL BALL BEARING	*n*	WATER-SEALING RING
		o	SHAFT SLEEVE

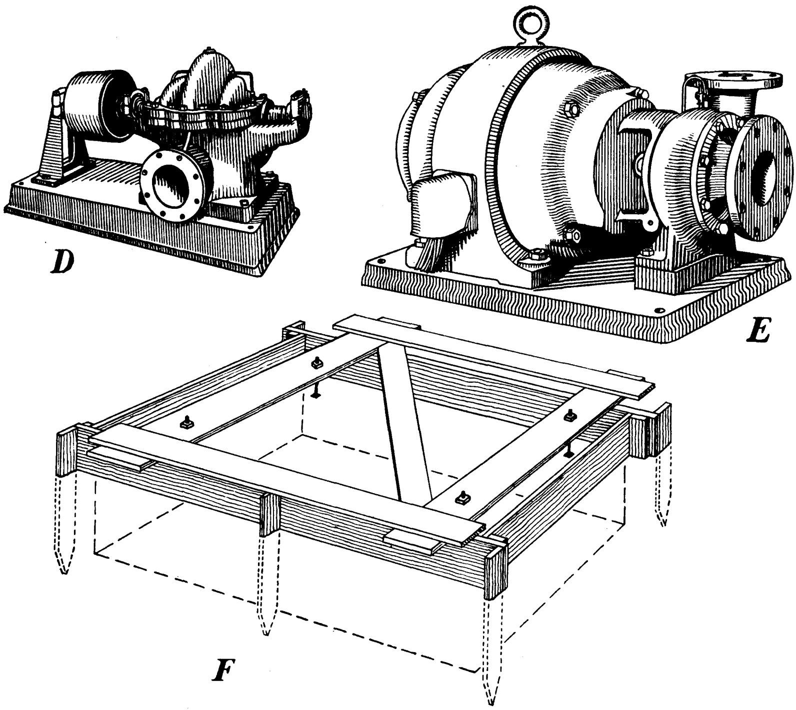


FIGURE 5.—*A*, Impellers: *a*, Open-type and *b*, closed-type: *B*, single-stage, single-side-suction centrifugal pump for belt drive; *C*, cross section of *B*; *D*, high-grade, well supported, single-stage, double-suction, enclosed-impeller centrifugal pump; *E*, close-coupled, electric-driven centrifugal pump; *F*, frame holding anchor bolts in place on a form for a concrete foundation for *E*.

In purchasing a centrifugal pump for farm irrigation, it is important to choose a pump that fits the job. Centrifugal pumps operate best under the conditions for which they are designed, and a pump that does not fit its job may deliver a good stream of water and yet waste a large amount of power. Power, whether from electricity or gasoline, must be paid for, including wasted power.

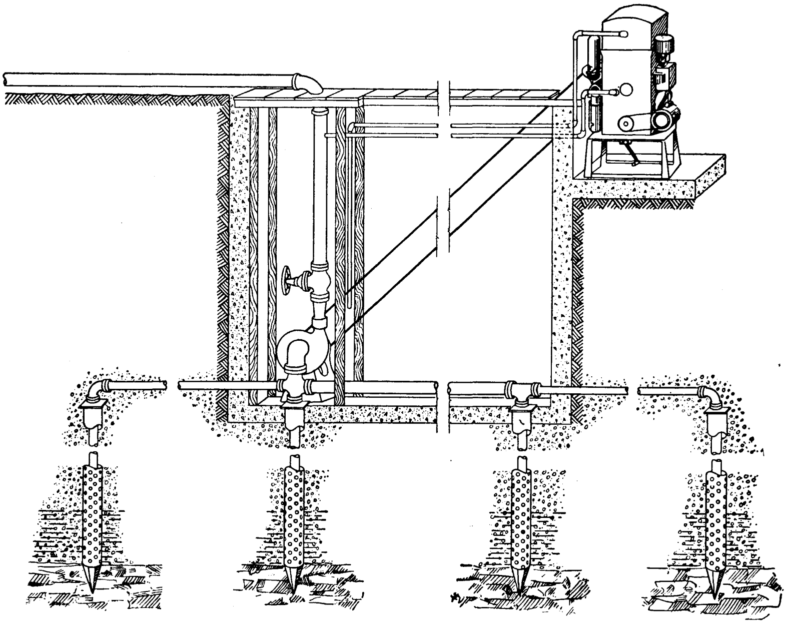


FIGURE 6.—Horizontal centrifugal pump set in concrete pit, to pump from several connected wells. The pit is required because the suction lift from the ground surface is too great.

In general, where a centrifugal pump draws water from a well the suction pipe or hose should be independent of the well-casing pipe. In this respect the installation of a centrifugal pump differs from that of a displacement pump, as with the latter a separate suction pipe is not necessary even with a driven well. Figure 6 shows an acceptable arrangement for pumping from a battery of wells with a centrifugal pump.

Starting a Centrifugal Pump

A centrifugal pump must be primed. A common way, if the discharge pipe is short, is to place either a gate valve in the discharge pipe or a flap valve at its end and a common hand pump at the petcock tapping in the top of the pump chamber. By operating the hand pump with the valve closed the air is exhausted from the suction pipe and pump chamber and water is drawn into the pump. Another way of priming is to set a foot valve in the lower end of the suction pipe and then fill the suction pipe and pump chamber with water from a barrel or tank. After the first priming each season this supply tank may be filled by a small branch pipe that takes water from the

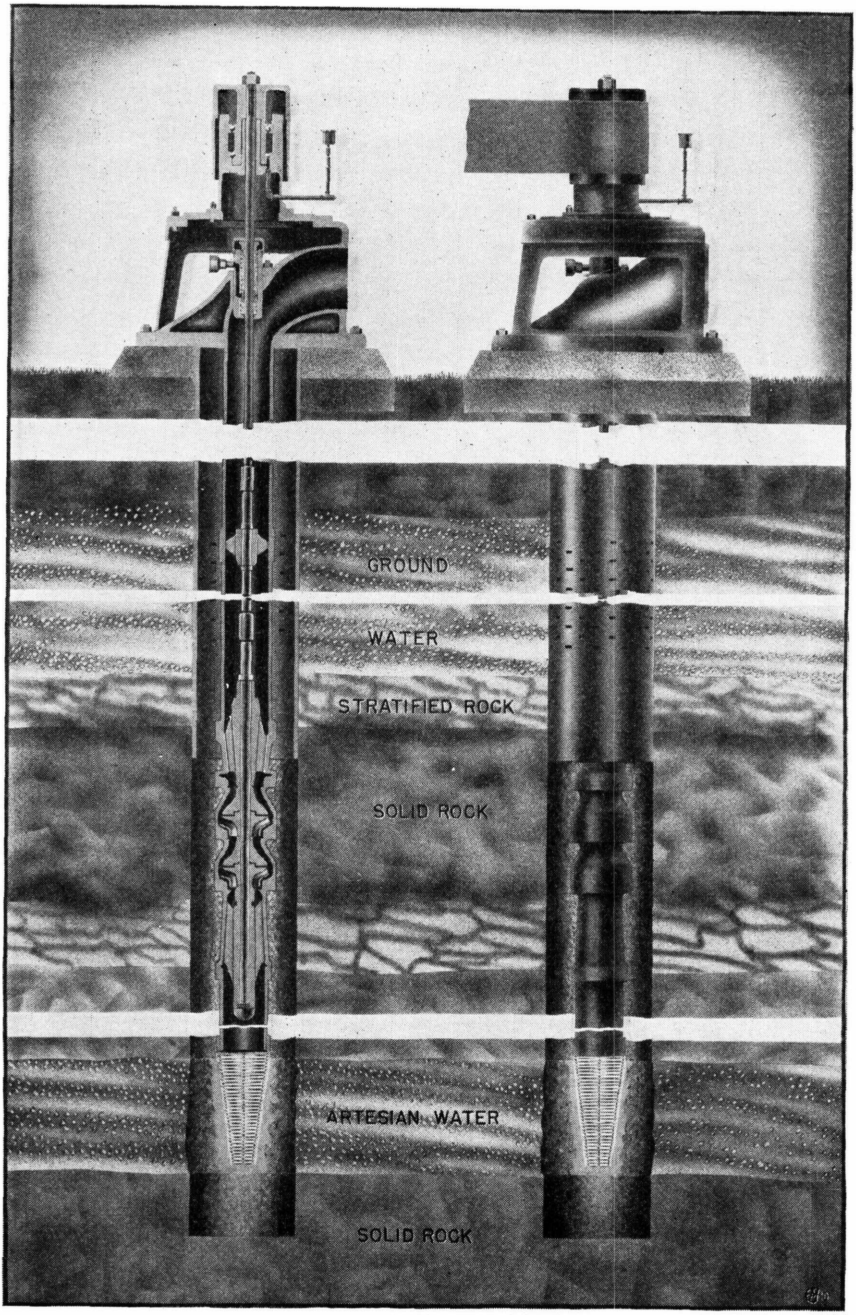


FIGURE 7.—Deep-well turbine pump operated by half-turned belt.

discharge pipe. No hand pump is needed, but it is important that the foot valve closes tightly when not supplying water to the pump and that it has a water passage large enough for the regular pump operation. Generally the foot valve should be one size larger than the suction pipe.

It is advisable to start a centrifugal pump with the gate valve in the discharge pipe closed and allow the water to be whirled around inside the pump chamber until the impeller gets up to speed. This is absolutely necessary with pumps that are hard to start because of the heavy load. When the impeller is fully up to speed, open the gate valve slowly and permit water to start flowing. Close the gate valve slowly before stopping the engine or motor.

A centrifugal pump should not be run when it is empty, as water is commonly depended on for lubrication and lack of it even for a short time may injure the pump. The pump should be thoroughly primed—that is, water should completely fill the suction pipe or hose and the pump chamber—each time before the pump is started. It is unwise to run a fully primed centrifugal pump for too long a time with all the valves closed so that no water can be discharged, because there is a tendency to heat even if the water is only whirled around inside the pump casing.

Deep-Well Turbine Pumps

A development of the centrifugal pump with its shaft vertical appears in the deep-well turbine pump (fig. 7). Under this heading are commonly grouped not only the true turbine that has centrifugal-type impellers of the enclosed variety with diffusion vanes to guide the water as it leaves each impeller, but also deep-well pumps of similar appearance that are equipped with mixed-flow and axial-flow impellers. In axial-flow impellers the flow is parallel to the axis; they get away from the centrifugal principle entirely and are direct-thrust pumps of the propeller type. Pumps of these three types are made for wells as small as 4 inches in diameter and can handle a relatively large volume even in such a small borehole. Deep-well pumps of the group discussed in this paragraph are made for quarter-turn belt drive, direct drive from a vertical-shaft electric motor mounted directly above, and for angle-gear drive. By the use of many impellers, water may be raised from as great a depth as is likely to be desired for irrigation purposes. Thirty to forty feet of head per stage or bowl is often allowed in determining how many impellers such a pump should have. This type of pump is likely to wear rapidly if required to pump water containing much sand. It is necessary that the wells in which these pumps are installed be straight, and it is very desirable that they be absolutely plumb. The bowls that house the impellers or turbines should be placed below the standing water level in the well, and at least the lowest one should be below the operating water level.

Air-Lift Pumps

If a deep well yields much sand with the water or is crooked, it may be desirable to use an air-lift pump to raise the water. The operating efficiency of the air lift is not great, seldom exceeding 33⅓ percent except in recently designed equipment. It has, however,

three good points; it can be used in a crooked borehole, it can handle extremely sandy water without substantial damage, and all the machinery connected with it is above the ground surface where it may readily be serviced.

The air-lift pump (fig. 8) consists essentially of an air compressor and compressed-air storage tank above the ground and an eduction pipe and a small air-inlet pipe, equipped at the bottom with a suitable foot piece, in the well. The purpose of the foot piece is to release into the water in the lower end of the eduction pipe a series of air bubbles that will form a mixture of water and air lighter than the surrounding water in the well. The purpose of the eduction pipe is to lead to the top of the well the mixture of water and air that will be forced to rise because of the difference in weight.

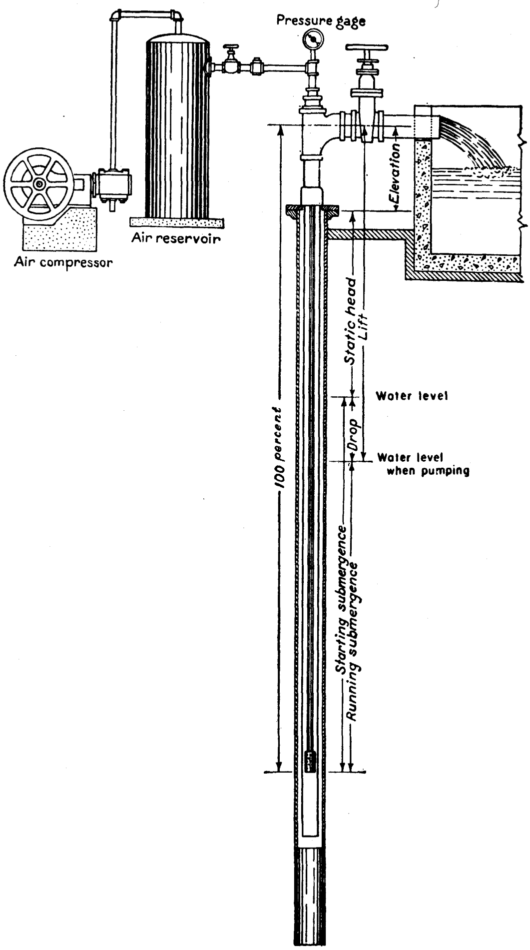


FIGURE 8.—Air-lift pump.

In order to raise water to the ground surface with the majority of air-lift pumps now in use, it is necessary that water fill at least two-thirds of the well. Recent improvements in design make it possible to raise water to the ground surface if water fills three-fifths of the well when pumping starts and fills two-fifths after getting into operation. An efficiency as great as 50 to 55 percent is attainable. If it is desired to put the water from the well under pressure, as for sprinkling irrigation, it will probably be necessary to use a centrifugal pump at the ground surface.

Displacement Pumps

Displacement pumps (fig. 9), sometimes called piston, plunger, or cylinder pumps, are used to a small extent in supplemental irrigation, although the many recent improvements in centrifugal pumps are reducing the number. Their primary field now appears to be in small sprinkling-irrigation systems that use not more than about 75 to 80 gallons per minute and draw water from a battery of small driven

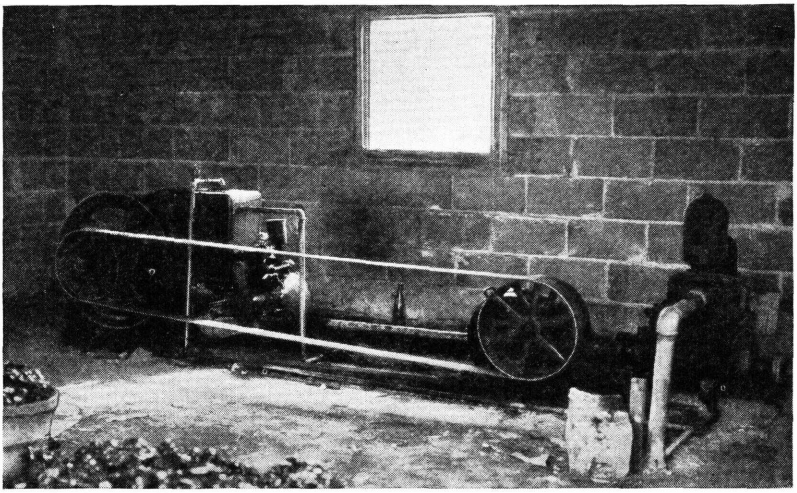


FIGURE 9.—Pumping outfit using displacement pump drawing from small driven well.

wells or from some other source with a high suction lift up to about 22 feet. If in good condition, they are self-priming; they are superior to the centrifugal because they do not lose their priming with the intake of a small quantity of air but will continue pumping almost any combination of water and air they can get. They may be attached directly to the casing of a driven well.

A Pump to Fit the Job

Table 2 gives recommendations for types of pumps suitable for supplemental irrigation at sea level under common supplemental-irrigation conditions. The stated suction lifts must be appropriately reduced for pumping plants at higher altitudes. The figures are based on a maximum practical suction lift of 15 feet for centrifugal pumps of good grade and in good condition, and of 22 feet for displacement pumps. This suction lift of 15 and 22 feet at sea level is reduced to 11 and 16.2 feet, respectively, at an elevation of 8,000 feet. Since the quantity of water handled by a pump decreases as the suction lift increases, it is extremely desirable to keep the suction lift at the minimum.

Table 2 may be used to suggest pumps suitable for other conditions. If, for instance, the lift is 19 feet, the pump may be installed at the ground surface as for an 18-foot lift with a somewhat reduced quantity of water handled; or it may be placed in a pit as would be necessary for a 26-foot lift, although a more shallow pit would serve for the 19-foot lift than for the 26-foot lift.

TABLE 2.—*Suggestions for suitable pumping equipment under certain conditions*

Water supply [1]	Sprinkling irrigation	Surface irrigation	Subsurface irrigation
Large lake, pond, or stream. Lift to ground surface not over 10 feet.[2]	Use horizontal centrifugal pump.	Use horizontal centrifugal pump.	Use horizontal centrifugal pump.
Large lake, pond, or stream. Lift to ground surface 22 feet.[3]	Use horizontal centrifugal pump set low on bank or supported just above water.	Use horizontal centrifugal pump set low on bank or supported just above water.	Use horizontal centrifugal pump set low on bank or supported just above water.
Large lake, pond, or stream. Lift to ground surface 50 feet or over.	do	do	Question advisability of pumping for subirrigation.
Battery of small driven wells (2 inches and under) not over 80 g. p. m. required. Lift to ground surface not over 18 feet.[4]	Use displacement pump directly attached to pump casing.	Use displacement pump directly attached to pump casing.	Use displacement pump directly attached to pump casing.
Battery of small driven wells (2 inches and under) not over 80 g. p. m. required. Lift to ground surface 26 feet.[4]	Use displacement pump in pit directly attached to pump casing.	Use displacement pump in pit directly attached to pump casing.	Use displacement pump in pit directly attached to pump casing.
Large well. Lift to ground surface not over 10 feet.	Use horizontal centrifugal pump.	Use horizontal centrifugal pump.	Use horizontal centrifugal pump.
Large well. Lift to ground surface 22 feet.	Use horizontal centrifugal pump in pit.	Use horzontal centrifugal pump in pit.	Use horizontal centrifugal pump in pit.
Large well, straight vertical borehole; clear, sand-free water. Lift to ground surface 50 feet or over.	Use turbine-type deep-well pump.	Use turbine-type deep-well pump.	
Large well, crooked borehole; water heavily charged with abrasives. Lift to ground surface 50 feet or more; well depth 3 times lift.	Use air-lift pump with centrifugal booster pump at ground surface.	Use air-lift pump	

[1] Lift includes friction, and ground surface means ground surface of field near pump.
[2] If more than 2,000 g. p. m. is required use a propeller pump.
[3] If more than 4,000 g. p. m. is required use a mixed-flow pump, a pump with a flow parallel to the axis and with an impeller of the propeller and centrifugal types combined.
[4] If more than 80 g. p. m. is required or lift is greater than 26 feet, avoid use of small driven wells.

At sea level, for instance, if the water supply is a battery of driven wells, not more than 80 g. p. m. is required and the suction lift plus friction in the suction pipe will not exceed 18 feet, then table 2 shows that a displacement pump should be used. If the conditions are all as stated above except that the suction lift plus friction is 26 feet, it is recommended that a displacement pump be used but that the pump be placed in a pit at least 4 feet deep so as to reduce the suction lift to 22 feet. A deeper pit is desirable but not strictly necessary; however, a pit 8 to 10 feet deep would beneficially lower the suction lift. The corresponding increase in head on the discharge side will ordinarily cause very little trouble.

POWER OUTFITS

Unless there is enough difference in elevation so that gravity will deliver water from the water supply to the distribution field, pumping machinery will be necessary to cause flow. Wherever pumping is necessary, the height to which the water must be raised should be considered, as it directly affects the power requirement. However, if a tractor that is also used for other farming operations is to be

utilized for power and the maximum load comes properly within the tractor's power, a difference in height to which the water must be raised is probably not important.

Internal-combustion engines are the most common power used for driving pumps, and electric motors are next. Lack of available electrical service has an important effect on this relationship, but rate schedules also have a bearing. Internal-combustion engines that have spark-plug ignition and gasoline for fuel are most common, although heavier fuels are used. A few internal-combustion engines of the Diesel and semi-Diesel type are used. The use of the cheap Diesel fuel is desirable, but the limited number of hours' operation a year scarcely warrants the cost of a Diesel engine except perhaps for the units designed for 24-hour-a-day operation in the drier edge of the supplemental-irrigation area or for the irrigation of rice or on farms where the engine is needed for other work a large part of the year. If a material reduction in the cost of Diesel engines should be made, probably many would be used in irrigation. Elimination of stand-by or minimum charges for electric power so that an irrigator paid only for power used would increase the use of motors.

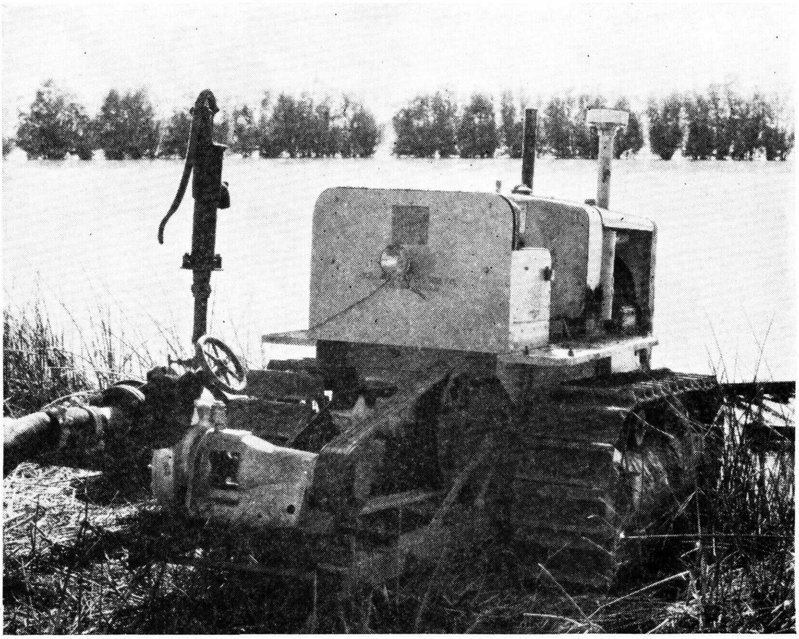


FIGURE 10.—Centrifugal pump with multiple V-belt drive, mounted on removable platform attached to tractor.

Tractors are a desirable source of power as they may be idle or at least may be readily released from other work in periods of drought. Some farmers use a pump installed in a permanent location and drive it from the tractor-belt wheel by means of a flat belt (fig. 3). Others prefer to have the pump portable and attached to the tractor by removable brackets or a removable platform. With such arrangements, pumps are sometimes driven direct by power take-off and sometimes by V-belt drive (fig. 10).

During the last few years, however, whether wisely or unwisely, the majority of farm irrigation outfits in the region have been powered with old automobile engines. This plan permits the use of an outfit with which the farmer is familiar. If in good repair and of the horsepower to operate efficiently at a suitable speed, the old automobile

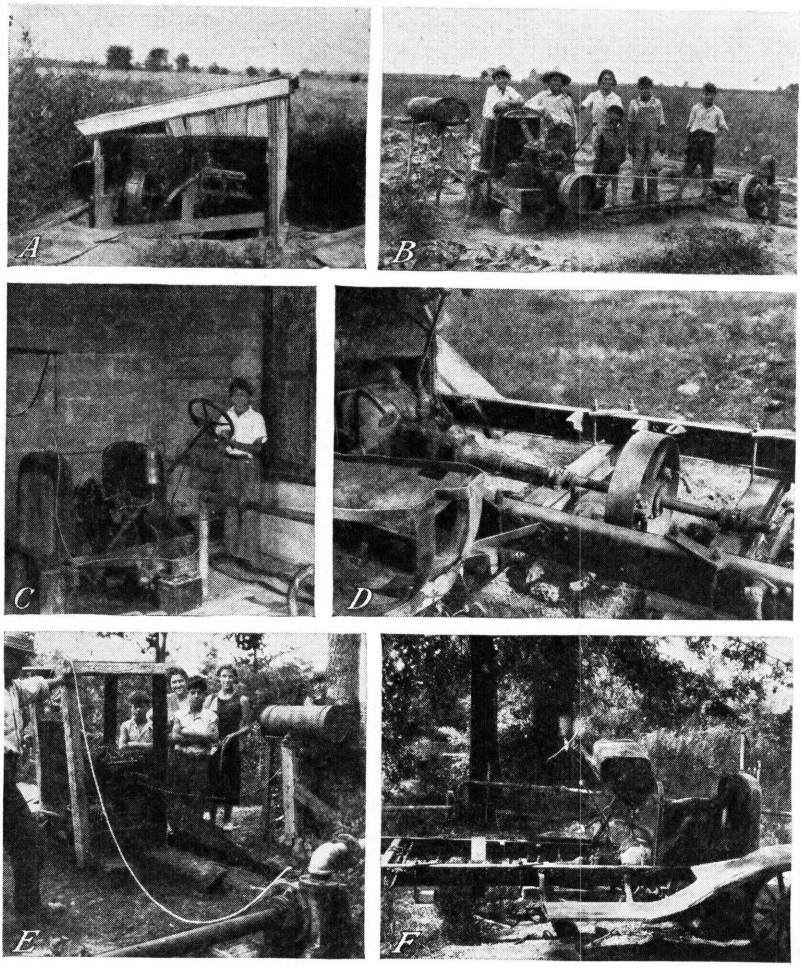


FIGURE 11.—Auto-powered pumping outfits: *A*, In frame shelter; *B*, in the open; *C*, in cement-block pump house in original mounting; *D*, cut-off drive shaft supported on wooden crosspieces with belt wheel attached; *E*, an arrangement showing hose for supplying cooling water; *F*, view showing pump connections.

engine makes a cheap and serviceable power outfit. The author has seen many small installations, however, in which the automobile engine so heavily overpowered the pump that the excess cost of gasoline would in a few years have paid for the cost of a new engine of the proper horsepower. Figure 11 shows several installations as actually used.

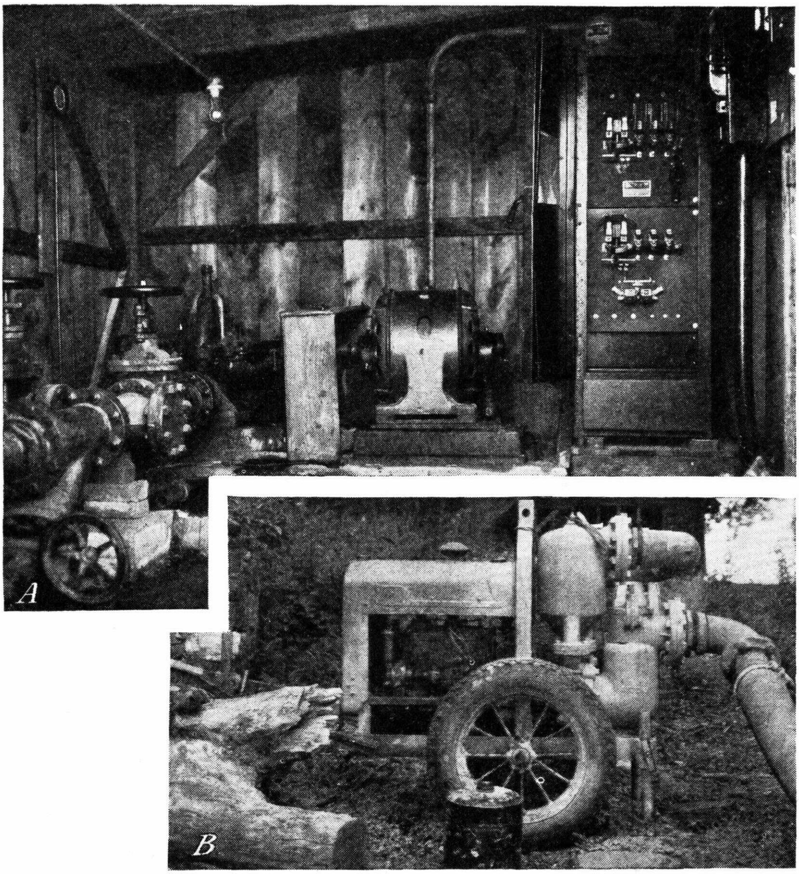


FIGURE 12.—*A*, Permanently installed high-grade electric pumping equipment; *B*, trailer-mounted portable pumping unit.

If electric power is available at a satisfactory rate and is near enough to the proposed pumping-plant site so that connection may be made at small expense, an electric motor may be satisfactory for driving an irrigation pump. Owing to the shortness of the irrigation season and the unpredictable irregularity of the need for power, there are many localities in which electricity is not economical because of the monthly stand-by or minimum service charges that must be paid whether power is used or not. Many power companies permit disconnection for the season of nonuse in the winter and will generally make no stand-by or minimum charge until connection is again made at the farmer's request. A farmer is seldom able to escape excessive charges during wet summer months after current has once been turned on in the spring, however, unless he is willing to have his winter disconnection made early and thus lose his chance to irrigate in late summer or early autumn. This condition, coupled with the fact that it is generally necessary to run wires some distance to reach supplemental-irrigation pumping sites, has limited the use of electricity. Where three-phase current is available and squirrel-cage motors may

TABLE 3.—*Approximate horsepower required for irrigation*

[Efficiency of pumping plant, 50 percent of theoretical. Use for estimating purposes only]

Quantity per minute (gallons)	Horsepower required for an elevation of—																
	10 feet	15 feet	20 feet	30 feet	40 feet	50 feet	60 feet	70 feet	80 feet	90 feet	100 feet	125 feet	150 feet	175 feet	200 feet	250 feet	300 feet
	Hp.	*Hp.*	*Hp.*	*Hp.*	*Hp.*	*Hp.*	*Hp.*	*Hp.*	*Hp.*	*Hp.*	*Hp.*	*Hp.*	*Hp.*	*Hp.*	*Hp.*	*Hp.*	*Hp.*
5	0.025	0.038	0.05	0.07	0.10	0.12	0.14	0.16	0.20	0.22	0.25	0.31	0.37	0.43	0.50	0.62	0.75
10	.050	.075	.10	.15	.20	.25	.30	.35	.40	.44	.50	.62	.75	.87	1.00	1.24	1.50
15	.075	.113	.15	.22	.30	.37	.45	.52	.60	.68	.75	.94	1.12	1.31	1.50	1.88	2.25
20	.100	.150	.20	.30	.40	.50	.60	.70	.80	.90	1.00	1.25	1.50	1.75	2.00	2.50	3.00
25	.125	.188	.25	.37	.50	.62	.75	.88	1.00	1.12	1.25	1.56	1.87	2.18	2.50	3.12	3.75
30	.150	.225	.30	.45	.60	.75	.90	1.04	1.20	1.35	1.50	1.87	2.25	2.62	3.00	3.74	4.50
35	.175	.263	.35	.52	.70	.87	1.05	1.22	1.40	1.58	1.75	2.19	2.62	3.15	3.50	4.38	5.25
40	.200	.300	.40	.60	.80	1.00	1.20	1.40	1.60	1.80	2.00	2.50	3.00	3.50	4.00	5.00	6.00
45	.225	.338	.45	.67	.90	1.12	1.35	1.56	1.80	2.02	2.25	2.81	3.37	3.94	4.50	5.62	6.75
50	.250	.376	.50	.75	1.00	1.25	1.50	1.74	2.00	2.24	2.50	3.12	3.75	4.37	5.00	6.24	7.50
60	.300	.450	.60	.90	1.20	1.50	1.80	2.10	2.40	2.70	3.00	3.75	4.50	5.25	6.00	7.50	9.00
70	.350	.525	.70	1.05	1.40	1.75	2.10	2.44	2.80	3.14	3.50	4.38	5.25	6.12	7.00	8.76	10.50
80	.400	.600	.80	1.20	1.60	2.00	2.40	2.80	3.20	3.60	4.00	5.00	6.00	7.00	8.00	10.00	12.00
90	.450	.675	.90	1.35	1.80	2.25	2.70	3.14	3.60	4.04	4.50	5.62	6.75	7.87	9.00	11.24	13.50
100	.500	.750	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	6.25	7.50	8.75	10.00	12.50	15.00
125	.625	.938	1.25	1.87	2.50	3.12	3.75	4.36	5.00	5.62	6.25	7.81	9.37	10.94	12.50	15.62	18.75
150	.750	1.125	1.50	2.25	3.00	3.75	4.50	5,24	6.00	6.75	7.50	9.37	11.25	13.12	15.00	18.74	22.50
175	.875	1.313	1.75	2.62	3.50	4.37	5.25	6.12	7.00	7.88	8.75	10.94	13.12	15.31	17.50	21.88	26.25
200	1.00	1.500	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	12.50	15.00	17.50	20.00	25.00	30.00
250	1.25	1.875	2.50	3.75	5.00	6.25	7.50	8.75	10.00	11.25	12.50	15.62	18.75	21.87	25.00	31.24	37.50
300	1.50	2.25	3.00	4.50	6.00	7.50	9.00	10.50	12.00	13.50	15.00	18.75	22.50	26.25	30.00	37.50	45.00
350	1.75	2.625	3.50	5.25	7.00	8.75	10.50	12.25	14.00	15.75	17.50	21.87	26.25	30.62	35.00	43.74	52.50
400	2.00	3.000	4.00	6.10	8.00	10.00	12.00	14.00	16.00	18.00	20.00	25.00	30.00	35.00	40.00	50.00	60.00
450	2.25	3.375	4.50	6.75	9.00	11.25	13.50	15.75	18.00	20.25	22.50	28.13	33.75	39.37	45.00	56.26	67.50
500	2.50	3.750	5.00	7.50	10.00	12.50	15.00	17.50	20.00	22.50	25.00	31.25	37.50	43.75	50.00	62.50	75.00
600	3.00	4.50	6.00	9.00	12.00	15.00	18.00	21.00	24.00	27.00	30.00	37.50	45.00	52.50	60.00	75.00	90.00
700	3.50	5.25	7.00	10.50	14.00	17.50	21.00	24.50	28.00	31.50	35.00	43.75	52.50	61.25	70.00	87.50	105.00
800	4.00	6.00	8.00	12.00	16.00	20.00	24.00	28.00	32.00	36.00	40.00	50.00	60.00	70.00	80.00	100.00	120.00
900	4.50	6.75	9.00	13.50	18.00	22.50	27.00	31.50	36.00	40.50	45.00	56.25	67.50	78.75	90.00	112.50	135.00
1,000	5.00	7.50	10.00	15.00	20.00	25.00	30.00	35.00	40.00	45.00	50.00	62.50	75.00	87.50	100.00	125.00	150.00
2,000	10.00	15.00	20.00	---	---	---	---	---	---	---	---	---	---	---	---	---	---
3,000	15.00	22.50	30.00	---	---	---	---	---	---	---	---	---	---	---	---	---	---

be used, a motor may be purchased for less than a new gasoline engine of equal horsepower. Many rural electric-power lines do not have enough capacity to permit the use of large squirrel-cage motors; hence motors with special types of windings to give better starting or running characteristics are required. Any electric motor in a pit over a well or in any place that is likely to be damp should have special moistureproof windings.

A pumping unit particularly adapted to local conditions is found occasionally. Examples of such units appear in figure 12.

For making estimates of the power required to drive a pump, a pump efficiency of 50 percent is often allowed, although somewhat more or less efficiency may be actually secured. Table 3 indicates on the above basis the horsepower required to pump various quantities of water against various amounts of total dynamic head. It is, however, suitable only for making rough approximations of horsepower requirements.

For more precise determinations of the power required of the engine or motor, the following formula may be used:

$$\text{Horsepower} = \frac{\text{(gallons per minute)} \times \text{(total dynamic head in feet)}}{3{,}957} \times \frac{100}{\text{(efficiency of pump)}} \times \text{(type-of-drive factor)}$$

The efficiency of the pump should be expressed as percent; for example, 55, 70. For the type-of-drive factor the following figures seem to fit the ordinary farm irrigation system: For flat-belt drive, 1.10; for V-belt drive, 1.03; for direct connection, 1.00; for angle-gear drive, 1.03. It should be noted that the horsepower figured in the above way is net horsepower at the engine or motor shaft and represents the necessary rated power of the engine or motor under continuous load.

For satisfactory operation it is desirable to provide slightly more power than is needed. For a gasoline or Diesel engine the maximum power at the intended number of revolutions-per-minute operating speed should be at least 25 percent greater than the constant load power figured above. Electric motors are commonly so rated that they can stand the temporary over-loads that may occur under operating conditions.

For low operating cost it is desirable to use as small a driver as is suitable if an electric motor or a gasoline engine is to be used, provided the outfit is sturdily built. Although any given electric motor uses somewhat less electricity when the load is light than when it is heavy, the actual energy consumption does not vary greatly from nearly full load down to small load. For a gasoline engine as normally used under farm conditions, the gasoline consumption does not seem to vary nearly so much with the size of the load as with the size of the engine. In other words, the gasoline consumption ordinarily is related to the rated horsepower rather than to the load the engine is pulling. The Diesel engine is different; fuel consumption varies with the load being handled.

Over the life of a reasonably well-kept gasoline engine, the gasoline consumption probably averages about 0.1 gallon per rated horsepower per hour. For an electric motor the energy consumption is probably

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in the vicinity of 1 kilowatt-hour per rated horsepower-hour. For a Diesel engine in the sizes ordinarily used for farm irrigation and kept in reasonably good condition, the fuel consumption may be expected to run in the vicinity of 0.6 pound per actual horsepower-hour over the life of the equipment. This would indicate about 0.085 gallon per actual horsepower-hour of power developed if a fuel oil weighing 7 pounds per gallon were used.

PUMP AND POWER CONNECTIONS

In most supplemental-irrigation outfits, power is transmitted from the driver to the pump by means of a flat belt (figs. 2, 5, 7, 9, and 11). The usual rules regarding transmission of power apply except that, since the irrigation service is so intermittent, it may be economical to buy some of the less expensive types of belts. Belt pulleys should be wider than the belts that run on them. Direction of rotation should be such that the tight side of the belt comes at the bottom of the belt pulleys, and the distance between centers should be at least several feet. If the centers of the pulley shafts must be close together, a weighted or spring-controlled idler or other means of keeping the belt tight should be provided, or a multiple-V-belt drive should be used (fig. 10). V-belt drives are suitable but have not been widely used as yet. Their widest use in irrigation is in connection with outfits in which the pump is carried on a shelf or bracket attached to a tractor (fig. 10).

Direct drives are common with electric-motor-driven centrifugal or deep-well-turbine pumping units. They are less common with gasoline-engine-driven centrifugal pumps. For direct connection pump and driving outfit must be suited for operation at the same number of revolutions per minute. A flexible coupling is generally provided between motor and pump with electric units. There are two notable groups of exceptions: (1) Some of the smaller units, the so-called close-coupled units in particular, in which the motor is mounted directly on the pump shaft; and (2) some of the more recent deep-well-turbine pumps, in which the pump shaft extends through a hollow shaft in the motor and the two shafts are fastened together at the top. A flexible coupling is also provided between a gasoline engine and the pump it drives, if directly connected. If in addition a clutch is provided to release the load when starting, the clutch is commonly built into the engine and the flexible coupling installed between the clutch and pumpshafts. Flexible couplings, it should be realized, are suitable only for taking care of minor misalinements, and every effort should be made to construct the unit so that nearly perfect alinement of the connected shafts is secured.

The geared type of speed reducers or increasers is not used to any extent in supplemental-irrigation service, probably because of cost. Angle-gear drives are suited to the operation of vertical-shaft pumps, and since drives with various speed ratios are obtainable, the horizontal shaft of the drive may be readily connected directly to the engine shaft through a suitable flexible coupling, or universal joint, or a pair of them.

If all the machinery is purchased as a pumping unit from one manufacturer, suitable power connection between the pump and the motor or engine may be assumed. If, however, the irrigator assembles his

own unit, consideration of the proper size of the power connection or power-transferring mechanism will be necessary. If a new pump is purchased, as is recommended, the pump manufacturer will, in all probability, be glad to recommend the size and type of suitable driving equipment, and to furnish data as to the proper rate of rotation (number of revolutions per minute) of the pump shaft and the engine or motor horsepower required.

Wherever a fully equipped automobile chassis is used for the basis of a pumping unit a clutch and flexible couplings are already at hand. Figure 11, *D* and *F*, show such pumping plants. Numerous automobile engines running at one-half to three-fifths of the maximum number of revolutions per minute allowed by the manufacturer, which is a good rate of rotation for the continuous duty of irrigation service, are also running at a speed just suitable for pump operation.

If an automobile engine is used to drive the pump, it is generally desirable to provide additional cooling capacity through bypassing some water from the pump to the radiator, as is illustrated in figure 11, *C*, *E*, and *F*. In some engines no radiator is used; the bypassed water from the pump is supplied directly to the lower hose fitting on the engine block, and a suitable waste-water line is attached to the upper hose fitting.

Engine-speed indicators are often of value. On automobile-chassis equipment, the original speedometer, if in working order, will indicate whether the engine is keeping up to speed. For each engine there is a certain definite rate of rotation that will generally give the most satisfactory irrigation—for most, an engine speed equivalent to 20 miles per hour. At the end of the season the total mileage indications may be used to determine the number of hours of operation for the year, and from that record a check can be kept on the consumption of gasoline and oil per hour of operation to determine when maintenance service is needed. For example, if at the end of the irrigation season the speedometer (or more strictly the odometer) indicates that the engine shaft has turned over enough times to drive an automobile 2,000 miles and an engine speed equivalent to 20 miles per hour has been maintained, then the engine has operated for 100 hours that season. Fuel and oil consumption and cost of operation can be determined on an hourly basis that will be comparable from year to year whether wet or dry.

Pressure and vacuum gages are often a great assistance in locating trouble if the plant is not working just right.

INSTALLING A PUMPING PLANT

Pump and Engine

Pumps should be located as near the source of water supply as practicable and at the lowest elevation consistent with other factors. Several arrangements of pump and power units are shown in figures 5, *E*; 9; 10; 11, *B*, *E*, and *F*; and 12. For permanent installation the pump and driver should be placed upon a level and solid foundation, or, if necessary, on two separate foundations. For the smaller pumping outfits heavy wooden foundations will do. For small belt-driven installations a cheap arrangement sometimes used is bolting the pump and engine to the opposite ends of two heavy timbers fastened rigidly together.

Concrete foundations are best. A rough rule for size is a foundation 6 inches longer and 6 inches wider than the machine that is to rest on it and a depth equal to at least two-thirds the height. The top of the foundation may be about 6 inches above the floor of a pit. It should, however, be made with its top surface about one-half inch lower than the level at which the machinery is to be set to allow for final leveling and grouting, as described on pages 26–27.

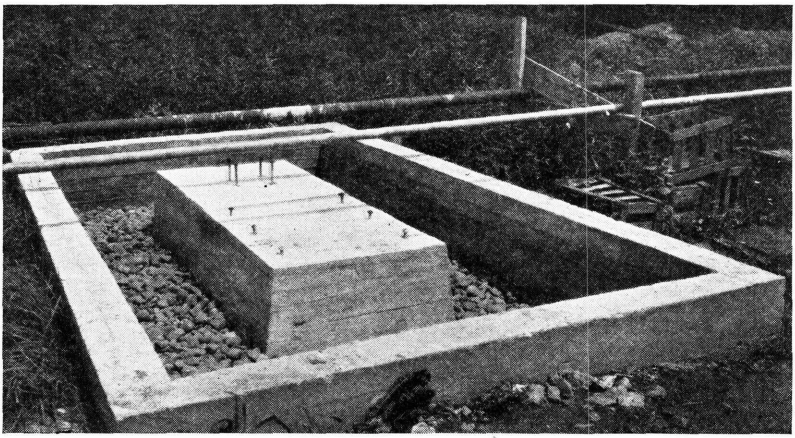

FIGURE 13.—Concrete foundation for a direct-connected automobile-engine-driven centrifugal pump, engine, and pump house.

Upward through this foundation surface should project the threaded ends of the anchor bolts that are to hold the machinery in place (fig. 13). The threads on these bolts should be extended farther along the stem than is customary, and the bolts should stick up 1 to 2 inches farther than they are likely to be needed. They should be so located that when the machine is in place they will extend through the bolt holes or slots of the bedplate up far enough to receive the washer and nut. The head ends of the bolts, projecting through large-sized washers, should be set in the concrete with ordinary pipe thimbles large enough to allow a ⅜- or ½-inch clearance all around the bolt. The manufacturers of the pump and engine will furnish plans showing the location of these foundation bolts, and the foundation may be placed before the machinery arrives. To place the anchor bolts accurately make a light but thoroughly braced framework to hold the bolts and thimbles in position while the concrete is poured. It is advisable to set up the machine on the loose boards, then fasten them together rigidly and mark the bolt locations (fig. 5, *F*).

A 1:2:4 concrete (1 part of portland cement, 2 parts of clean sand, and 4 parts of crushed rock or gravel) makes a good foundation if properly mixed and cured. Directions for mixing concrete are in Farmers' Bulletin 1772, Use of Concrete on the Farm.

After the concrete base has hardened, place the machinery on it, bring it to the desired elevation, and level it carefully in every direction by wedging under the bedplate. Now see that the revolving parts turn over easily. With a centrifugal pump it will generally be necessary to loosen the packing in the stuffing box. Do not, however, obtain ease of turning by loosening the bearings. When all strain is

removed and the machinery is level, the rotating parts should turn easily. Fill in between the bedplate and the concrete base with the one-half inch or so of grouting that will be needed to give the bedplate a good bearing all around. This grouting may be made of a mixture of equal parts of cement and sand, with enough water to make it work easily. When this has hardened tighten the foundation bolts, being careful not to spring the bedplate. After the bolts are tightened, be sure that the rotating parts still turn easily by hand. After the piping has been attached to the pump, it should again be tested for ease of turning.

The whole pumping outfit should be protected from the weather and from dust and dirt. It should be housed in a building or room not used for any other purpose and so placed within this room that both pump and driver are easy to get at from all sides. If the power unit is a gasoline engine, the ignition system is likely to give the most trouble. Great care should, therefore, be given to its adjustment, and it should be carefully protected from moisture and dirt. If the power unit is an electric motor the windings must be kept dry. Before freezing weather sets in each winter all water should be drained from the pump and pipes, inside as well as outside the pump house.

Pipe and Fittings

The pipes on both the suction and the discharge sides of the pump should be large enough to reduce friction loss as much as possible; they should never be smaller than the pump tappings and preferably one to two sizes larger. For long lines this larger size of pipe is essential. Great care must be used in tightening joints to see that no strains are put on the machinery. All pipe lines should run as directly as possible and have no unnecessary bends.

As a large part of pump trouble is on the suction side, great care should be used to see that this is properly installed. As before stated, the pump must be well within the suction lift of the operating water level, and a suction pipe at least one size larger than the pump intake tapping is desirable. The reduction in size of the suction pipe should be made at the pump connection, preferably by the use of a tapered fitting. Such fittings may be obtained from the pump manufacturer. The joints must all be tight, as an air leak is fatal to good operation. If the pipe is not dropped directly downward from the pump into the water supply, it must be so sloped that there are no pockets where air can collect. The lower end of the suction pipe should extend far enough below the water surface that air will never be drawn in. For a small outfit pumping from a large body of water a 2-foot submersion will be ample. For larger pumps 4 or more feet will be needed, and when the water is pumped from a sump or collecting chamber even greater submersion may be necessary, owing to the tendency of the water to cup down over the intake.

If the pumping is to be done from surface bodies of water, a well-made strainer with ample openings should be provided to keep sticks and trash from being drawn into the suction pipe and pump. If the water is to be used for sprinkling irrigation, a large strainer or strainer box with many holes should be provided. These holes should be small enough that any trash or foreign material that can get to the suction pipe will not clog the nozzles. Many overhead-pipe sprin-

kling systems use nozzles with openings as small as 0.029 inch in diameter. For these a screen with holes not larger than 0.025 inch should be used. A large screen surface is necessary if the relatively large quantity of water necessary to supply the pump is to get through the screen. A good screen greatly reduces the field attention necessary to clear clogged nozzles. Punched brass, stainless steel, and special alloy plates with suitable punchings are available. Owing to the cost of such equipment much woven-wire screen and even cloth screen is used. These, having approximately square openings, are not so effective unless of fine mesh. Since cloth screens are apt to rot very fast it is advisable to have them mounted on removable frames for quick replacement of the screening material.

If the discharge pipe is only a few feet in length, it may be of the same size as the pump fitting; if longer, it should be enlarged as near the pump as possible, preferably through a tapered fitting. It should have as few bends as possible.

Certain valves and piping on the main pipe lines around the pump are necessary for priming the pump and for protecting it from very high water pressure that may be accidentally set up. A gate valve installed in the discharge pipe close to the pump may be a help in priming or reducing excessive load on the driving unit when starting a system that has a long discharge pipe or that operates against a high total head. A check valve should be installed between the gate valve and the pump. Every sewer-pipe system should have an open pressure-relief pipe near the pump (p. 33).

TRANSPORTATION

From the gravity source, the flowing well, city main, or, more commonly, from the pump, water must be transported to the field that is to be irrigated. If other conditions are favorable, a ditch may be used for this purpose; in this area, however, pipe lines seem to be preferred. Pipe lines may be permanent or portable. All portable pipe lines are of metal, but permanent lines may be of metal, wood, or concrete, or under certain low-pressure conditions of terra-cotta or vitrified-clay sewer pipe.

With both pipes and open ditches there is a certain resistance to the flow of water that has to be overcome. This resistance is due to friction between the water and the sides of the ditch or channel or between the water and the walls of the pipe. For this reason, a slope or grade has to be given to ditches and a head has to be allowed to overcome friction in pipes. The quantitative amounts of these factors are discussed on pages 30 to 32 and page 38.

In planning for any piping system the size of the pipe or pipes should be chosen that is most suitable for the quantity of water to be transported. Large pipe costs more than small pipe but often permits the use of a smaller engine or motor, which requires less fuel or electricity to operate the system. In general if the farmer is planning supplemental irrigation as a permanent addition to his farm, a pipe larger than the smallest that could be used will be the cheapest in the end. A smaller pipe may be desirable if the farmer has other uses during the nonirrigating season for an engine or motor with excess power.

The sizes of transportation pipes recommended for carrying given quantities of water are shown in table 4. These are somewhat larger than the minimum sizes that will deliver the specified quantity of water. The pipe is generally at least one and possibly more sizes larger than the discharge-pipe-connection fitting the pump.

TABLE 4.—*Sizes of steel and cast-iron pipe recommended for transporting given quantities of water*

Size of pipe (*Inches*)	Quantity of water transported per minute		Size of pipe (*Inches*)	Quantity of water transported per minute		Size of pipe (*Inches*)	Quantity of water transported per minute	
	Steel pipe	Cast iron pipe		Steel pipe	Cast iron pipe		Steel pipe	Cast iron pipe
	Gallons	*Gallons*		*Gallons*	*Gallons*		*Gallons*	*Gallons*
¾	3-4		2½	39-65	43-75	5	230- 420	250- 460
1	5-7		3	66-110	75-120	6	420- 720	460- 790
1¼	8-14		3½	110-170	120-190	7	720-1, 000	790-1, 100
1½	15-22		4	170-230	190-250	8		
2	23-38	25-42						

Transportation and main distribution lines that are laid underground should be deep enough not to interfere with cultivation and sloped so that they can be drained at convenient places. The provision for drainage commonly consists of a small opening near the bottom of the pipe at every low point in the piping system. The openings are plugged when the system is in use. If the pipes of the piping system rise continuously, even though gradually, from the pump to their distant ends they can be drained from a single valve or plug located near or in the pump house. In cold climates the pipes should be drained before freezing weather in the fall.

In installing permanent irrigation mains underground the trenches ordinarily are first opened by a plow and deepened by further plowing, the loosened material is thrown out, and the trench is completed by hand.

METAL PIPES

Metal pipes are most common for irrigation purposes. They range from the very durable cast-iron pipe, through standard wrought steel, with either threaded or field-welded joints, and the comparatively thin-walled portable pipes used with the new types of portable sprinkling equipment, to the light, thin-walled galvanized-iron rain-leader pipes. Each has its uses and under certain conditions has given satisfactory service. Portable pipes of the newer type are discussed under sprinkling irrigation.

From among the metal pipes, permanent galvanized and black wrought-steel pipe are most common for humid-irrigation. Sizes below 3½ inches are generally galvanized, and those 3½ inches and larger are generally black, although 6-inch galvanized pipe is being used in sprinkling irrigation. For any sprinkling system, galvanized pipe has the advantage that it is less likely to scale than the untreated or black pipe and so causes less trouble with nozzles or screening devices, particularly for the overhead-pipe systems. As a deposit in the bottom of an underground pipe, scale does no harm. If once carried up to the lateral pipes, there is great danger of clogging nozzles.

Most of the older irrigation systems that use permanent steel-pipe mains have the pipes fastened together by threaded joints. Many of the more recent installations that have pipes 3½ inches or larger use welded joints put together in the field. Among these are many systems in which the transportation pipe consists of second-hand boiler tubes welded together in the field. Where field-welded joints are used it is common both to cut the holes for the branch pipes and to attach the fittings with the welding equipment. The ends of the pipe lengths to be welded are preferably faced with a bevel cut. On some farms that have welding equipment for other farm purposes, the pipe-line welding is done by the farm mechanic. On most farms, however, welding experts are hired for the job.

Either threaded or field-welded pipe may be assembled on timbers laid across the trench so the joints can be fitted easily and tightly. A length of 200 feet or more can be fitted together and allowed to sag gradually into the trench as the length is increased. Welded joints may also be made at ground-surface level with the pipe lying on timbers. The newly assembled unit is joined to the previously assembled pipe line before all of it has sagged into the ditch. Welded joints may also be made with the pipe lying in the ditch. Steel pipe for welding may be obtained in lengths of about 40 feet.

It is a common practice for the welder to make the openings in the pipe and attach the fittings for the pipes that conduct the water to outlets. A desirable saddle fitting with threaded outlet-connection openings is available for connecting branch pipes to welded main lines. Many branch-pipe connections up to 1½ inches in size, however, are simply ordinary threaded pipe couplings welded to the hole burned in the main pipe for the branch opening.

Table 5 gives the number of feet for each 100 feet of threaded-joint steel pipe that must be added to the vertical lift in order to overcome friction. If the high side of a field to be irrigated is 15 feet above the surface of the pond from which the water is pumped and it is desired to use 3½-inch pipe and to deliver 100 gallons of water per minute, table 5 indicates that to determine the height the pump must work against 2.22 feet for each 100 feet of pipe will have to be added to the 15-foot difference of elevation. If the high edge of the field is 400 feet from the water supply, this additional amount is 8.88 feet, and the pump must work against 15 feet plus 8.88 feet, or 23.88. If the farmer wishes to pass 100 gallons a minute through 400 feet of 2½-inch pipe, the additional head due to friction would be 4×12 or 48 feet, and the pump in that case would have to work against a total head of 63 feet. If he wishes 100 gallons of water per minute to flow through a perfectly level 3½-inch threaded steel pipe, he will have to start the water 8.88 feet higher than the pipe; through a level 2½-inch pipe, he will have to start it 48 feet higher.

Cast-iron pipe is the most durable of all the metal pipes used in irrigation. The thinner types of this pipe are well suited for use in most supplemental-irrigation systems, either for the entire main-supply piping or for the high-pressure parts of systems which are able to use less strong pipe in other sections. Class A or class B cast-iron water pipe, standard cast-iron gas pipe, or extra-heavy cast-iron soil pipe, are all suitable for this use. For irrigation service it is proper to use the soil pipe for heads up to 100 feet, the gas pipe

and class A water pipe up to 150 feet, and class B water pipe up to 250 feet. The head is the greatest head that will come on the pipe at any point and includes any head due to friction.

TABLE 5.—*Number of feet to be added to vertical lift for each 100 feet of threaded-joint steel pipe to overcome friction*

[Based on the Williams-Hazen formula with c=100]

Quantity of water per minute (gallons)	Number of feet to be added with pipe of the indicated size												
	¾-inch	1-inch	1¼-inch	1½-inch	2-inch	2½-inch	3-inch	3½-inch	4-inch	5-inch	6-inch	7-inch	8-inch
	Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
5	10.5	3.25	0.84										
6	14.7	4.55	1.20										
8	25.0	7.80	1.59	0.95									
10	38.0	11.70	2.05	1.43	0.50								
12		16.40	4.30	2.01	.70								
14		22.00	5.70	2.68	.94	0.32							
16			7.30	3.41	1.20	.41							
18			9.10	4.24	1.49	.50							
20			11.10	5.20	1.82	.61	0.25						
25			16.60	7.80	2.73	.92	.38						
30			23.50	11.00	3.84	1.29	.54						
35				14.7	5.10	2.72	.71	0.32					
40				18.8	6.60	2.20	.91	.41					
45				23.2	8.2	2.76	1.15	.51					
50					9.9	3.32	1.38	.62	0.34				
60					13.9	4.65	1.92	.89	.47				
70					18.4	6.20	2.57	1.11	.63	0.21			
80					23.7	7.90	3.28	1.46	.81	.27			
90						9.80	4.08	1.80	1.00	.34			
100						12.00	4.96	2.22	1.22	.41			
120						16.80	7.00	3.10	1.71	.58	0.23		
140						22.30	9.2	4.20	2.28	.76	3.0		
160							11.8	5.25	2.91	.98	.36		
180							14.8	6.30	3.61	1.22	.47		
200							17.8	7.7	4.40	1.48	.56	0.28	
220							21.3	9.6	5.20	1.77	.69	.33	
240								11.6	6.2	2.08	.83	.39	0.22
260								13.3	7.2	2.41	.95	.47	.25
280								15.2	8.2	2.77	1.10	.53	.28
300								17.8	9.3	3.14	1.26	.62	.33
350								22.6	12.40	4.19	1.68	.82	.45
400									16.0	5.40	2.10	1.03	.56
450									19.8	6.70	2.52	1.24	.71
500									24.0	8.10	3.15	1.50	.84
550										9.6	3.70	1.81	1.01
600										11.3	4.35	2.18	1.20
650										13.2	4.90	2.50	1.40
700										15.1	5.80	2.90	1.60
750										17.2	6.60	3.30	1.78
800										19.4	7.50	3.65	2.00
850										21.7	8.40	4.20	2.26
900											9.20	4.50	2.50
950											10.1	5.10	2.80
1,000												5.60	3.10

Soil pipe is furnished in 5-foot lengths and the others in 12- and 16-foot lengths. Bell-and-spigot pipe, and not flanged pipe, should be used, and because of the saving in labor required for jointing, the 16-foot is preferable. Instructions for making joints are given in Farmers' Bulletin 1426, Farm Plumbing. Cast-iron pipe should be covered at least 15 inches over its top, and where it passes under farm roads, it should be protected from injury by the wheels of heavily loaded wagons.

The frictional resistance in cast-iron pipe is less than in threaded-joint wrought-steel pipe; therefore, the same-sized pipe in cast iron will carry somewhat more water under the same pressure conditions.

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Table 6 shows the friction to be overcome in cast-iron pipe 10 years old. Allowances have been made for the roughening of the pipe with age.

TABLE 6.—*Friction to be overcome in each 100 feet of 10-year-old cast-iron pipe or sewer pipe when carrying certain quantities of water*

[Based on the Williams-Hazen formula with c=110]

Quantity of water per minute (gallons)	Friction to be overcome in pipe of the indicated size—						Quantity of water per minute (gallons)	Friction to be overcome in pipe of the indicated size—					
	3-inch	4-inch	6-inch	8-inch	10-inch	12-inch		3-inch	4-inch	6-inch	8-inch	10-inch	12-inch
	Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*		*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
50	1.0	0.25					750			6.0	1.47	.48	
60	1.5	.40					800			6.75	1.67	.55	.21
70	2.0	.55					850			7.5	1.85	.62	
80	2.6	.80					900			8.3	2.00	.68	.25
90	3.3	.90					950			9.2	2.25	.75	
100	4.0	1.00	0.12				1,000			10.2	2.50	.83	.33
120	6.0	1.4	.16				1,100			12.0	3.00	.98	.38
140	7.9	1.9	.20				1,200			14.2	3.45	1.15	.45
160	9.9	2.5	.25				1,300				4.00	1.37	.51
180	12.0	3.1	.32				1,400				4.50	1.54	.60
200	15.0	3.7	.45	0.10			1,500				5.20	1.76	.68
220		4.4	.55	.13			1,600				5.90	1.96	.75
240		5.1	.70	.17			1,700				6.60	2.22	.83
260		6.0	.80	.20			1,800				7.45	2.50	.95
280		6.9	.90	.24			1,900				8.25	2.77	1.08
300		7.8	1.0	.28	0.10		2,000				9.00	3.05	1.20
350		10.4	1.4	.35	.12		2,100				9.87	3.30	1.35
400		13.4	1.8	.47	.15	0.10	2,200				10.75	3.58	1.45
450			2.25	.57	.20		2,300				11.70	3.90	1.60
500			2.75	.70	.24	.12	2,400				12.60	4.20	1.70
550			3.3	.83	.28		2,500					4.53	1.87
600			3.8	.95	.32	.14	2,600					4.88	2.00
650			4.5	1.1	.38		2,800					5.60	2.30
700			5.2	1.27	.43	.18	3,000					6.4	2.63

Lightweight galvanized pipe of spiral-welded or seam-welded construction, similar to the portable pipe used in many systems, is suitable for permanent pipe in most localities if it can be supported above ground, as along a fence line. For use in Florida and other regions where the atmosphere is unusually destructive to all exposed steel construction, such pipes should be further protected with other coatings—asphalt paint or tar, for example.

VITRIFIED SEWER PIPE

Vitrified-clay sewer-pipe, also called terra-cotta pipe or salt-glazed pipe, can be made watertight under low pressure and is easily laid. It breaks, however, under pressure. A sewer-pipe line should not be used for a vertical head of water of more than 15 feet, which means a pressure of 6 pounds per square inch. For that reason it is not suited to sprinkling irrigation. Its use in surface irrigation is extremely limited.

In sewer pipe systems a larger pipe is generally used than would be necessary with metal pipes, in order to reduce the part of the total pressure that is due to friction and thus to reduce the total pressure. A glance at table 6 will explain this. Because of the very limited strength of sewer pipe, in planning any sewer-pipe system considera-

tion should be given to the point of greatest pressure. A dip or sag in the pipe line may be the point of greatest pressure. Ordinarily the pressure within a pipe is greater near the pump than at any more distant point along the pipe line unless the pipe line inclines downward from the pump so steeply that the friction in the pipe is less than the rate of fall. If a 6-inch sewer-pipe line, which requires a friction or pressure of 6 feet per 100 feet of pipe to transport 750 g. p. m. (table 6), drops uniformly down and away from the pump on a slope of 6 feet per hundred, the change in elevation will just balance the retardation due to friction and the pressure will be no greater near the pump than elsewhere. If, however, as is usual, the downward inclination of the pipe is less, say 5 feet per hundred, an additional pressure, 1 foot per hundred, will have to be supplied at the initial end. If such a pipe is 700 feet long the pressure near the pump will be 7 feet greater than at the far or outlet end of the pipe when the pump is running.

The profile of a sewer-pipe system with a rising irrigation main is shown in figure 14. Let us assume that the top of the most distant outlet, *d*, is at the same level as the center of the pump. Under operating conditions the pressure on the pump is 7 feet, all consumed in friction in the pipe line except for just enough, three-fourths of an inch or so, to allow the water to overflow the outlet at *d*. The pressure inside the buried sewer pipe at *b* is 4 feet greater, or 11 feet. The corresponding pressure at *c* is only 3 feet. Owing to the height of the open pressure-relief pipe near the pump the maximum pressure that can come on the pump, if all the valves were closed, would be 9 feet; the maximum on the sewer pipe at *b*, 13 feet; the maximum on the sewer pipe at *c*, 9 feet. The greatest pressure point in the system is at *b*, but the pressure is less than the recommended limit of 15 feet, so this system could be expected to work.

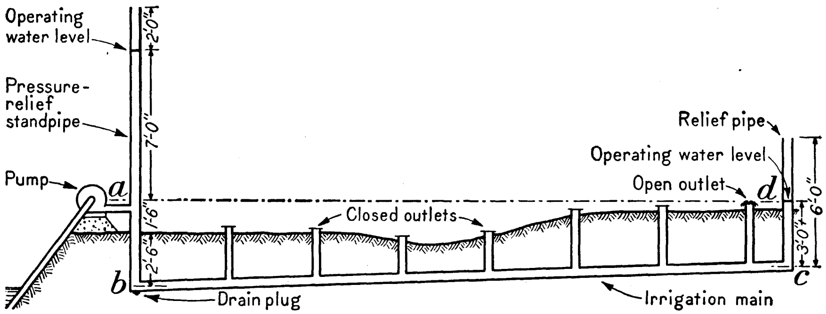

FIGURE 14.—Profile showing pressure on a sewer-pipe system.

None but the best grade of sewer pipe should be used. Pipe that is not well formed and pipe with cracks or broken ends should be rejected. The best way to test for cracks is to tap the pipe lightly with a hammer; a clear ring usually means a sound pipe.

The trench in which the pipe is laid should be dug deep enough to allow at least 18 inches of earth cover over the pipe after it is laid.

This cover will prevent injury to the buried pipe when a heavily loaded wagon or a tractor passes over it. The bottom of the trench should be scooped out to a rounding surface in order to bed the pipe properly. This is most easily done by digging a flat-bottomed trench and then scooping out a central channel with a tile scoop to a depth of one-third the outside diameter of the pipe (fig. 15). To allow the worker to move about in the trench without disturbing the pipe previously laid the flat-bottomed part of the trench should be dug about a foot wider than the outside width of the pipe. Holes for the bells of the pipe should be scooped out of the trench. A straight stick properly marked off can be used to space them.

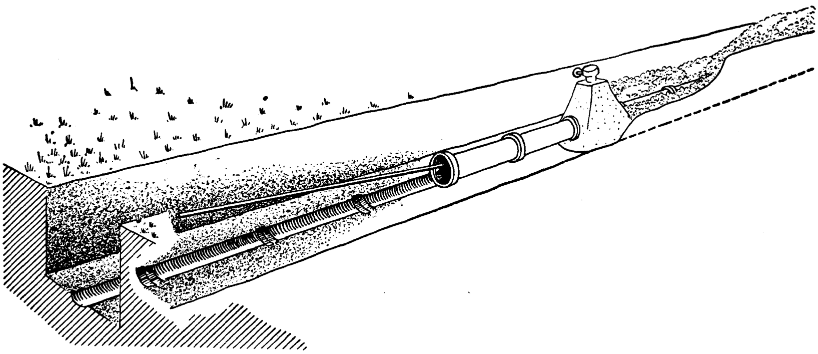

FIGURE 15.—Installing a vitrified sewer-pipe distribution system.

One contractor who has done a considerable amount of this work beds the pipe with the aid of water instead of scooping out for the bells. After the pipe is laid and the joints tested he throws in enough dirt to cover about three-fourths of the pipe. He then floods the ditch and after the earth has dried sufficiently he tamps it under the pipe.

Most irrigators now use both cement mortar and bituminous sewer-pipe joint compound, making one to four joints of the compound and then one of cement mortar. The advantages of this plan are that the bituminous compound is elastic enough to allow some give in the pipe line due to settling, temperature changes, etc., and that when the pipe is lying in the ditch farm workers seem able to make better cement joints than bituminous joints.

Units of two to five lengths of pipe connected with bituminous joints are readily made outside the ditch (fig. 16). Stack the lengths in a vertical position, bell ends up. Calk the lower space between the bell of one pipe and the spigot of the next to prevent the joint material from running out and wasting. Jute is the best calking material, but pieces of newspaper crumpled up and carefully tamped into place do very well. Since better joints are required for this work than for ordinary sewer work, leave at least two-thirds of the space to be filled with melted bituminous sewer joint compound. Use a heavy grade of compound—the one that weighs about 108 pounds per cubic foot is very satisfactory. For each joint about one-fourth pound of

compound per inch of pipe diameter is needed. Heat the compound in a kettle until it pours like water, but not above that point. Pour the melted compound into the joint—a skillet or ladle may be used for pouring—and leave the unit standing until cool.

After the joints have cooled the assembled units of several pipe lengths may be laid and joined with watertight joints, usually of cement mortar. The mortar should be tamped firmly into all parts of the bell. Great care should be taken to make sure that the under side of the joint is well cemented. To do this effectively it often is necessary to use a tamping tool. Such tools may be made of iron, but very satisfactory ones can be whittled out of wood. To smooth up the inside of the pipe in case any mortar works into it, a long-handled swab (fig. 16) made of gunny sacking is laid in the pipe with its handle projecting outside as shown in figure 15. When a section of pipe is added it is slid over the swab handle, and the swab is drawn toward the open end of the pipe.

The mortar for the joints should be made of clean, sharp sand mixed with an equal quantity of cement and just enough water to make the mixture fairly stiff. Only small batches should be mixed at a time, since it is not wise to use mortar that has stood longer than 15 minutes.

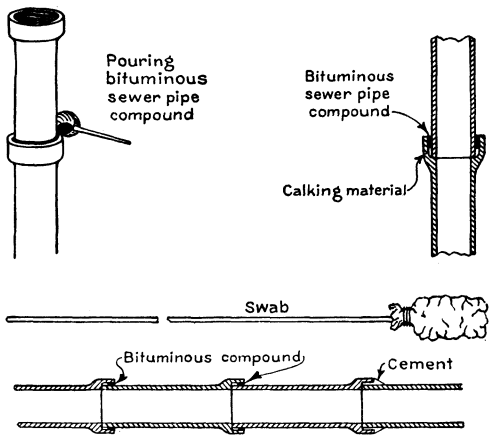

FIGURE 16.—Method of assembling vitrified sewer-pipe unit.

Outlet valves or hydrants are commonly spaced from 30 to 100 feet apart and are connected by short lengths of clay pipe to standard sewer-pipe tees placed in the main pipe line as it is laid. Each outlet is cemented firmly to a short riser pipe. In the best class of work a block of concrete is then cast around the tees and its short pipe, thus reinforcing the entire connection with the main (fig. 15). Wherever the soil is likely to freeze, this block of concrete should be tapered toward the top to guard against heaving.

Four-inch iron-pipe nipples for outlets and 4-inch cast-iron pipe caps to shut the water off (fig. 17) are sometimes used. Such openings are cheap, but the irrigator is likely to be sprayed with water when closing an outlet. Furthermore, it often is difficult to remove the caps because of rust. Trouble from this cause may be reduced by frequently coating the threads with graphite grease.

A better type of outlet is known as an alfalfa or orchard valve (fig. 18) and is widely used in western irrigation. It is ordinarily cemented to the top of the riser pipe. Since the opening is adjustable, regulation of the quantity of water discharged is possible. Another

convenient way of arranging an outlet where regulation is desired is to use a 4-inch or even a 3-inch steel-pipe nipple with a gate valve as shown in figure 15.

Combination standpipes and diversion boxes (fig. 19) may be constructed in fields where branch mains are wanted. Flow in outgoing pipes is regulated by slide gates or valves. The standpipe should be high enough to prevent overflow in ordinary operation.

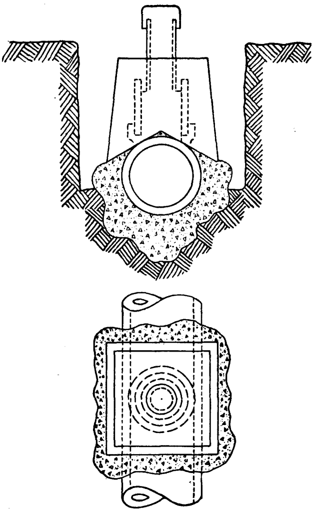

FIGURE 17.—Nipple and cap outlet from vitrified sewer-pipe distribution line.

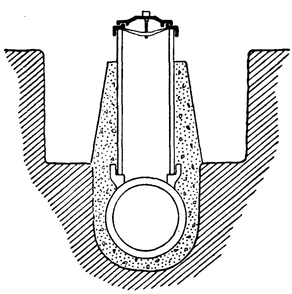

FIGURE 18.—Alfalfa- or orchard-valve outlet from sewer-pipe distribution line.

It is generally unwise to use sewer pipe under pressure where the ground freezes to a depth of more than a foot. The top of the pipe should be at least a foot below freezing, as considerable changes in temperature seem to cause trouble in sewer-pipe lines even though the pipe is buried below danger from heaving ground. The uprights leading from the main to the surface must be protected; otherwise heaving of the ground is apt to break the connection between the valves and the underground main. The tapered concrete block recommended on page 35 is designed in part to overcome this trouble. There should never be any projecting shoulder that heaving ground can raise; valves with projections should be placed several inches above the ground.

Sewer pipe used in the Northern States should be so laid that the slope will permit it to be drained easily. Drain cocks may be placed in the pipe at low places by cutting a hole in the pipe with a cold chisel and cementing in a short piece of 1-inch iron pipe connected to a cut-off valve or closed with a cap. The drain is set near the bottom of the pipe.

It is not safe to pump directly into a sewer-pipe system unless some sort of pressure-relief device is provided. The surest device for this purpose is an open standpipe with its top at an elevation a few feet above that of the highest ground to be irrigated. Then if the pump is operated with all the valves closed the standpipe will permit the water to overflow, thus preventing the pressure from bursting the pipe. The standpipe should be placed between the pump and the sewer-pipe line on the discharge side of the check valve if one is used. Similar standpipes should be placed near the closed ends of long laterals and of all laterals of even moderate length if the far ends are

at low elevations. A cheap and convenient standpipe may be made by cementing together a few joints of pipe.

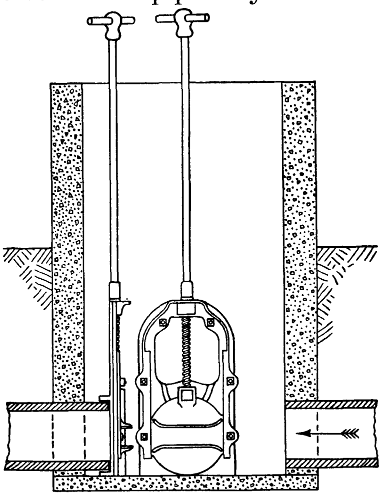

FIGURE 19.—Combination standpipe and diversion box, built of concrete.

If it is desired to use portable-pipe distribution with a sewer-pipe transportation system a special portable hood is necessary. Hoods arranged to fit the commercial irrigation valves may be purchased from the valve makers, but if outlets made of pipe fittings are used each irrigator must devise his own. A hood, as ordinarily made, consists of a pipe elbow of galvanized sheet iron arranged for attaching one end to the outlet fixture. The other end is commonly connected to an 8- to 12-foot length of canvas hose. The purpose of the hose is to give a flexible connection between the outlet and the portable-pipe lateral.

DITCH SYSTEMS

Although ditch systems have disadvantages due to the space they take up and the inconvenience they cause in wet as well as dry years, they warrant consideration owing to their lower initial cost.

The proper size of the ditch and its fall should be determined before excavation is begun. The size of the ditch will depend principally on its slope and the acreage to be watered. The grade should be kept as flat as is practicable. If water is taken from a gravity supply and the diversion point on the stream is high, the fall of most ditches depends on the soil. Steep grades cut down the size of the ditch, but trouble from wash-outs is likely if the soil is sandy or if the ditch is carried along a hillside. It is possible, however, to protect a steep ditch by lining it with concrete. Where there is no danger of injury through freezing, this concrete lining may be a thin, plastered coating put on with a trowel. More often a thicker lining with a chicken-wire reinforcement will be necessary and under some conditions a well-reinforced, rigid, concrete structure. Every effort should be made to locate the ditch so that it will be "in the ground" instead of carried on fills.

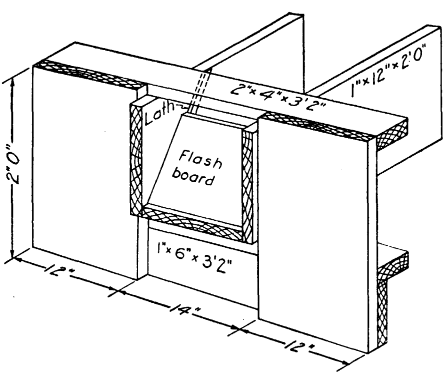

FIGURE 20.—Wooden head gate with one outlet.

A small ditch can be safely carried on a steeper fall than a large one. Table 7 gives the quantities of water that ditches of various sizes and fall will carry safely in soils not classed as sandy. For sandy soils the ditch should be wider and shallower and should have a slightly greater cross section in order to carry the same amount of water at the same grade. The cross-sectional areas of ditches of different sizes are given in table 7. The distribution ditches should be located on the higher parts of the field, either along its high side or along the tops of the ridges that may extend into it.

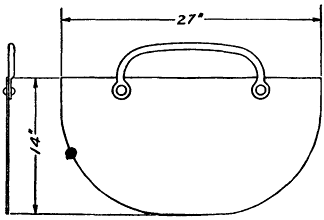

FIGURE 21.—Metal dam, or tappoon.

To handle the water as it comes from the larger supply ditches, several small structures are needed. It may be well to use wooden structures until the system has been thoroughly tested.

A wooden head gate is put in at the intake of most small ditches (fig. 20). It may have one, two, or three outlets. The water is best controlled by means of movable boards fitted into cleats nailed to the side of the box. At other points the water may be controlled either by filling the ditch with dirt at the proper places and cutting the bank with a shovel or by using canvas or sheet-iron dams that can be moved around (fig. 21). The top slat of a canvas dam is placed across the ditch and a little dirt is thrown on the canvas at the bottom and sides to put it into use. The sheet-iron dam is merely thrust into the ditch deep enough to stand the pressure of the water against it.

TABLE 7.—*Carrying capacities of ditches*

Size of ditch	Fall per 100 feet	Carrying capacity per minute	Size of ditch	Fall per 100 feet	Carrying capacity per minute
	Inches	*Gallons*		*Inches*	*Gallons*
Top width 2 feet, bottom width 1 foot, depth 6 inches, cross-sectional area 0.7 square foot.	4	340	Top width 4½ feet, bottom width 2½ feet, depth 1 foot, cross sectional area 3.5 square feet.	1	1,460
	6	410		1½	1,790
	8	480		2	2,070
	12	590		3	2,550
	18	720	Top width 5½ feet, bottom width 3 feet, depth 1 foot 3 inches, cross-sectional area 5.3 square feet.	1	2,620
Top width 3 feet, bottom width 1½ feet, depth 9 inches, cross-sectional area 1.7 square feet.	2	760		1½	3,220
	3	930		2	3,730
	4	1,070	Top width 7 feet, bottom width 4 feet, depth 1½ feet, cross-sectional area 8.2 square feet.	¾	4,150
	5	1,200		1	4,800
	6	1,320		1½	5,900
Top width 3 feet 8 inches, bottom width 2 feet, depth 10 inches, cross-sectional area 2.3 square feet.	2	1,190		1¾	6,380
	3	1,460	Top width 9 feet, bottom width 5 feet, depth 2 feet, cross-sectional area 14 square feet.	⅜	6,080
	4	1,690		½	7,070
				¾	8,700
				1	10,070

DISTRIBUTION

MAIN DISTRIBUTION LINES

The transportation pipe, or ditch, discussed in the preceding section carries the water from the pumping plant or gravity intake to the edge of the field that is to be irrigated. At this point this transportation pipe merges into and becomes the main pipe of the distribution system. Most main distribution pipes as here referred to differ from the transportation pipes only in that they have outlets at suitable intervals.

If the main pipe is portable, pipe lengths may be added or removed—as the point of discharging the water is changed, if a surface-distribution system is used; as the point of connecting the lateral is changed, if a portable-sprinkling or conveyor-pipe system is used. Many pumping plants are shut down while the laterals are being moved, and no valves are necessary. Figure 37 (p. 68) shows the pipe arrangement of a portable main pipe in a system that has its water supply within the irrigated field.

If a permanently installed main is used, permanently installed outlets are placed at suitable intervals. The spacing of these outlets depends on the type of irrigation. For use with the newer type of portable laterals carrying sprinkler heads, these outlets in the main pipe are commonly spaced at intervals equal to three times the distance the laterals are moved at a time. For overhead-pipe sprinkling irrigation a connection fitting is necessary at each location at which a lateral is used, whether the laterals are permanent or portable. For portable-conveyor pipe or hose the outlet connections commonly are 30 to 100 feet apart. The outlet connections for use with porous hose are often at shorter intervals although some are as great as 100 feet. In most porous-hose systems a suitable length of watertight conveyor hose is used between the outlet fitting and the distribution line. For eyelet hose used in orchards with rather close planted tree rows, most outlet connections are placed at every other tree row. With wider spacings a section of conveyor hose is likely to be used between the connection with the main and the eyelet hose.

Valves to control the rate of flow as well as to shut off the water when no irrigation is desired are commonly installed on the outlet-connection fittings. In many systems with outlets larger than 3 inches, however, the opening is closed with a cap or plug when not in use. Since these have no ready means of controlling the rate of flow when irrigating, the pumping plant is shut down when a shift is to be made. This is not necessary in many low-pressure systems; sufficient reduction in pressure can be secured by starting irrigation in the next area to make the shift without stopping the pump.

In most sprinkling systems and in many other irrigation systems the main pipe is the same size throughout its length. This has the advantage of giving the most nearly uniform pressure at the outlets. It also gives the most uniform distribution in the different sections of the field if the laterals are kept the same length of time in each position. The plan also has a very practical operating advantage if a portable main is used, as any piece of pipe can be placed in any part of the line. It is permissible to reduce the size of the end sections of some mains, as has been done in some of the large installations.

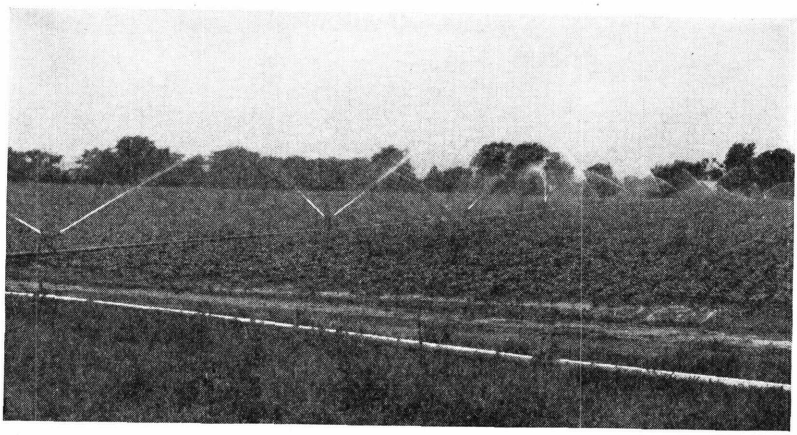

FIGURE 22.—Portable sprinkling irrigation in a New Jersey spinach field.

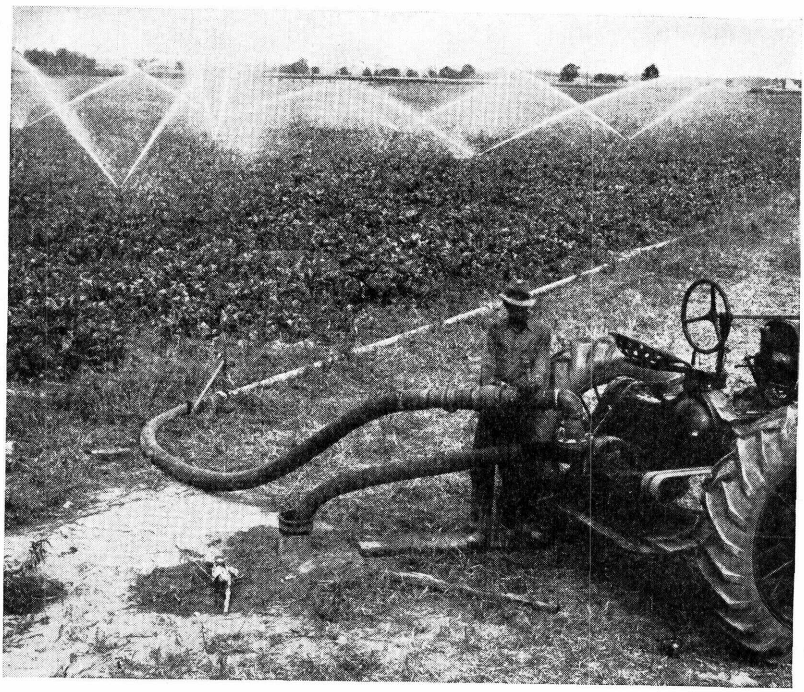

FIGURE 23.—Portable sprinkling irrigation of sugar beets near Urbana, Ohio. Only the water supply, the well, is stationary. The centrifugal pump, driven by a flat belt, is mounted on a bracket or shelf attached to the tractor and is removable. A short length of regular hose connects the short pump-discharge pipe with the portable main pipe along the edge of the field.

This reduction, however, should not be as great as might be inferred from table 4, because the difference in pressure at the nozzle lines is likely to be greater than desirable.

SPRINKLING IRRIGATION

Sprinkling irrigation delivers water in drops of spray from nozzles or sprinkler heads; the water is thrown through the air as the result of pressure in the pipes (figs. 22 and 23). No grading is required, and it may be used on any soil and topography. This method also makes economical use of water since sprinkling distributes it with fair uniformity and very little waste.

Portable-Pipe Systems

Portable pipes have recently reduced the cost of sprinkling irrigation to the point that in the Eastern States it is competing with surface irrigation. It has been introduced on many farms within the last 3 or 4 years. Its use has been increased by the development of several types of pipe couplings (fig. 24, *A*) and the production of lightweight readily portable welded steel pipes (fig. 24, *B*) suitable for carrying the pressures needed. This equipment makes it possible to assemble and disassemble a pressure-tight line of pipe quickly, and with the addition of suitable sprinklers, makes a very practical sprinkling lateral. An excellent feature of this system is that all the equipment may be removed from the field and stored when not in actual use.

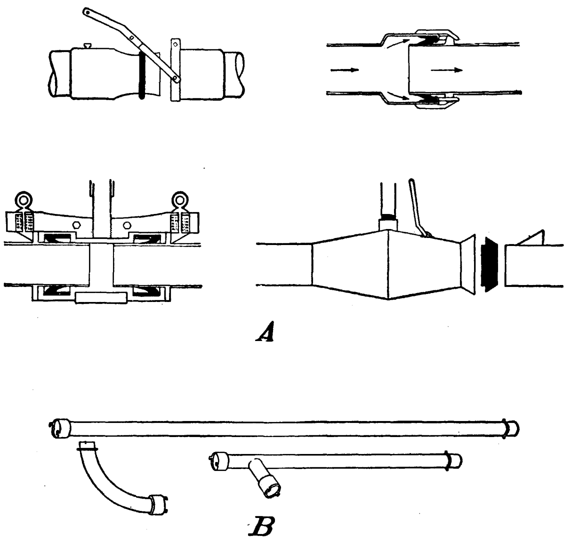

FIGURE 24.—Steel pipe and couplings suitable for portable irrigation systems: *A*, Several types of quick-assembling pipe joints; *B*, portable irrigation pipe and fittings.

The portable lateral is laid out at right angles to the main distribution line. The water passes out through sprinkler heads attached to short riser pipes. When the desired amount has been distributed over whatever ground can be reached, the flow of water is stopped, and the portable line is moved, pipe by pipe, to a new position. The process is repeated until the field is irrigated. Many farmers discontinue irrigation while the lateral is being moved. Others have a second line so that one may be in operation while the other is being moved.

The usual practice in moving sprinkler laterals is for one or two men to disconnect one pipe length at a time, carry it to its new location, and reassemble the line. A three-man crew can move two lengths at a time, and occasionally a larger crew moves more lengths.

The pipes used for portable sprinkling systems are either spiral or straight seam welded and have wall thicknesses ranging from 16 gage to as heavy as 10 gage. Such pipes, which are commonly galvanized, are available in 2-, 2½-, 3-, 4-, 5-, 6-, and 8-inch sizes. Most systems are made up of 20-foot lengths, although pipe lengths from 16 feet to 30 feet are available. Most systems have connection fittings for the vertical riser pipes in the couplings; some systems have the sprinkler-connection fittings welded into the sides of the pipes.

Riser pipes are commonly three-fourths of an inch in diameter, but 1-inch or 1¼-inch pipes are not too large for the larger-capacity sprinklers. The large pipe is preferable if the sprinklers are raised some distance above the pipe to get above the foliage.

Most of the sprinkler heads or nozzles are of the revolving type. The moving parts revolve about the top of the riser pipe in the direction of discharge of the water. One revolution per minute. or slightly less, seems to be the preferred rate of speed.

Sprinkler heads are spaced 16 to 40 feet apart in the portable lateral. They are designed to operate at pressures from 20 to 22 pounds per square inch for some of the small-range sprinklers to pressures of 55 to 60 pounds for some of the long-range large-capacity systems. Under these pressures the sprinkler heads deliver from 4 to 20 gallons per minute and wet a circle from 30 to 100 feet or more in diameter. These sprinklers generally do not wet uniformly the whole of the circular area to which they spread water. The sprinklers most commonly used, which have a range of wetted circle probably 60 feet in diameter, are placed 40 feet apart on the lateral and the lateral is moved 40 feet to one side at each change of setting. Sprinklers with a range of throw of 36 feet (72 foot-diameter of wetted circle) may be 40 feet apart on the lateral and the lateral moved either 40 or 50 feet at each change of location. Figure 25 shows some sprinkler heads with intermediate and fairly wide ranges of throw.

The quantity of pipe needed for sprinkling irrigation of any particular tract should always be determined for that tract. In relation to acreage there are certain minimum quantities of pipe below which the lengths of pipe cannot be reduced and the standards maintained. For a sprinkling system capable of supplying 1 inch of water per week, applied with nozzles that are adapted to a 40-foot sidewise movement of the laterals once in 2 hours, with a lateral 980 feet long, a minimum length of pipe, main and lateral together, allowing 20 minutes each time for shutting off the water, moving the lateral, reassembling, and starting, will be 1,680 feet, or approximately 25.4 feet per acre for the location of a permanent pumping plant on a favorably shaped tract. This condition is obtained with a well at the center of a rectangular tract 2,000 feet long and 1,440 feet wide. Such a tract would contain 66.1 acres. Most 66-acre tracts, because of shape or relative location of water supply, would require more pipe in order to make it possible to apply 1-inch depth of water in accordance with the operating conditions noted.

For 580-foot laterals under similar standards of operation 72 settings of the sprinkler pipes can be made in seven 24-hour days, and with the most favorably shaped tract and centrally located water supply, a tract of land 1,440 by 1,200 feet, containing 39.7 acres, can be watered. The minimum length of pipe per acre for a 40-acre tract with the water supply in a fixed location and the above-stated equipment-operating limits is 32.2 feet. Most 40-acre tracts are not so favorably shaped or so well located with reference to their water

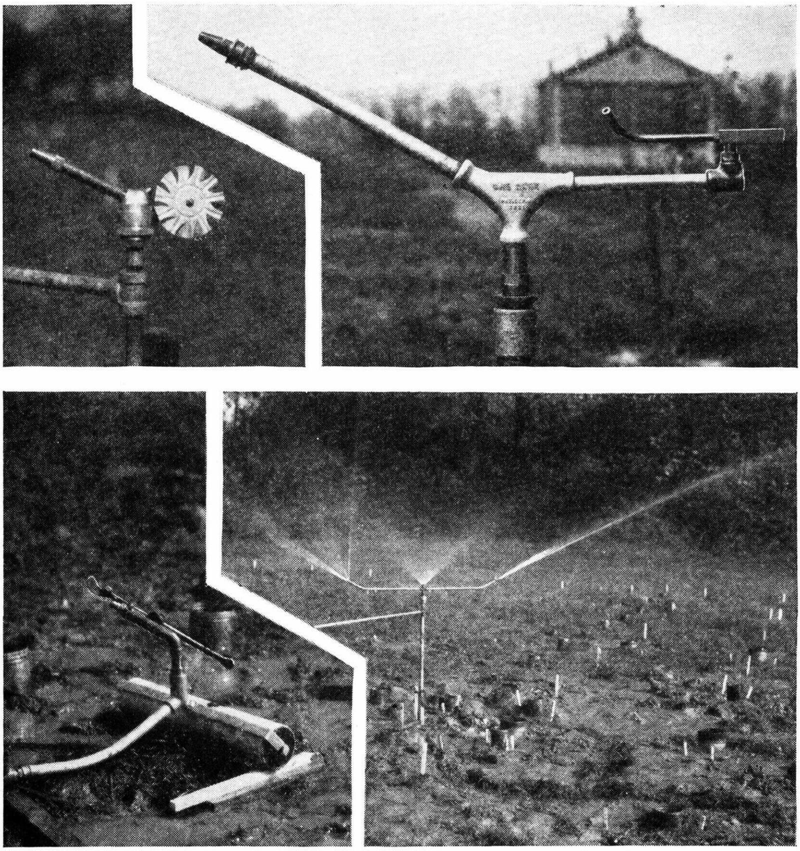

FIGURE 25.—Sprinkler heads adapted to portable irrigation.

supply. Forty-five to fifty-five feet of pipe per acre, or 1,800 to 2,200 feet for a 40-acre tract, is probably more nearly the average requirement on the operating basis outlined.

For small tracts small outfits are available that have sprinklers of lesser capacity and operate under lower pressures. The pipes are generally moved 20 feet at a setting, a pressure of 20 to 25 pounds or so is allowed for the sprinkler nozzles, and the rate of application is reduced to where the sprinkler laterals should be left in one place for 55 minutes. On this basis 1 acre-inch can be applied on a 3¾-acre tract in 7 days of 13 hours of pumping each. The minimum quantity of pipe required under such conditions is about 130 feet per acre. Nighttime operation is not anticipated.

The arrangement of pipes in the field and the length of laterals used depend on a number of factors—the size and shape of the tract to be irrigated; the available water supply, power, labor; the area to be covered; and the time in which it is desired to get over it.

The rate at which water may be withdrawn from the water source may always be a limiting factor, but in figuring the water requirement it is also always necessary to figure the requirement of one sprinkler lateral as the unit of water supply. If the laterals are 380 feet long and have 10 sprinkler heads that discharge an average of 12 gallons per minute each, the water requirement will be 120 gallons per minute per lateral. One lateral will irrigate at each setting a strip 40 by 400 feet in size, assuming that the nozzle wets a circle 58 feet in diameter and that the laterals are moved 40 feet along the main at each setting. The area of the irrigated strip 16,000 square feet is equivalent to 0.367 acre. As 1 acre-inch of water contains 27,152 gallons, 9,965 gallons (0.367$\times$27,152) must be supplied to the irrigated strip to cover it to a depth of 1 inch. If the water is supplied at the rate of 120 gallons a minute, it will take 83 minutes, or about 1⅓ hours at each setting of the sprinkler-pipe lateral to give a 1-inch irrigation to the strip being wetted. If sprinklers handling 15 gallons per minute are used, the sprinkler pipes will have to stay at one set-up for only 1 hour 6 minutes. If sprinklers handling 8 gallons per minute are used, 2 hours 5 minutes of irrigation will be needed.

Soil conditions also are a limiting factor in irrigation. Water should not be sprinkled onto a field any faster than the soil can absorb it. For that reason sprinkler capacity must be held down to a suitable amount for the soil of the tract being irrigated.

It is desirable that all the sprinklers operating at one time operate at the same pressure. This is not possible owing to friction in the pipes, but effort should be used in planning a system to keep the differences in pressure as small as possible. This is most easily done by using large pipe and short laterals. Friction in the laterals increases as the length of lateral and number of sprinklers increase. If long laterals are used, it is advisable to reduce the friction by using only every alternate or every third sprinkler at a time. Quick-acting connection couplings of the snap-on type for the nozzles are obtainable. It is better to move the nozzles along the lateral, one position at a time until the entire strip is watered rather than to move the whole half or third of the sprinklers as a group to another part of the lateral. In this way a sprinkler lateral remains in one position two or three times as long as it would if all sprinkler positions were used at one time.

Tables 8 and 9 give data on the pressures, quantities, and horsepower necessary at the initial end of laterals of different sizes and lengths to supply two kinds of sprinklers at 40-foot spacings along the laterals. These pressures are given as head, or the height in feet of the equivalent column of water. This is done because for the purposes of this bulletin it is generally easier to figure pressures in feet. In each case, however, the pressure acting on the last sprinkler on the line is given in pounds per square inch as that is the more common commercial rating. To convert figures giving pressures in pounds per square inch to equivalent feet of head multiply by 2.31; 30 pounds per square inch is equivalent to a head of 69.3 feet. The figures given for

the horsepower requirement are simply approximate figures based on an efficiency of 50 percent of the theoretical and show power consumption in supplying the lateral only. The power required to operate the system will be greater as additional power is needed to lift the water from the water supply and force it through the main to where the lateral connects.

The tables show the advantages of large pipe and of short laterals for this type of irrigation. For instance, table 8 shows that with sprinkler heads having a capacity of 9 gallons per minute under a pressure of 35 pounds per square inch it takes about 3 times as much horsepower to operate one 600-foot sprinkling lateral of 2-inch pipe as it does to operate two 300-foot laterals—23.3 as against 7.62. If, however, a 600-foot lateral is necessary, the horsepower may be kept low by using larger pipe. With 3-inch pipe only 6.71 horsepower is needed.

TABLE 8.—*Number of sprinklers, head, gallonage, and approximate horsepower (50-percent efficiency basis) necessary for portable sprinkler pipes of specified lengths, carrying sprinklers with a capacity of 9 g. p. m. at 35 pounds per square inch when pressure at most distant nozzle is 35 pounds*

[For sprinkler pipes only—does not include rest of system]

Length (feet)	Sprinklers	Head	Quantity per minute	Horsepower	Head	Quantity per minute	Horsepower	Head	Quantity per minute	Horsepower
	Number	*Feet*	*Gallons*		*Feet*	*Gallons*		*Feet*	*Gallons*	
		2-inch pipe								
200	5	87.5	45.5	2.00	2½-inch pipe			----	----	----
250	7	93.8	64.2	3.04	84.5	63.6	2.72	----	----	----
300	8	102.0	74.0	3.81	86.9	72.7	3.20	3-inch pipe		
350	9	113.0	85.0	4.86	90.6	81.9	3.75	84.3	81.0	3.44
400	10	129.0	96.3	6.30	94.6	91.8	4.39	85.7	90.6	3.92
450	12	150.0	119.0	9.02	100.0	110.0	5.56	87.7	109.0	4.83
500	13	186.0	136.0	12.76	112.0	123.0	6.96	90.6	117.0	5.34
600	15	267.0	173.0	23.3	129.0	144.0	9.39	96.2	138.0	6.71
		4-inch pipe								
700	18	86.3	163.0	7.11	159.0	181.0	15.5	107.0	168.0	9.10
800	20	88.9	182.0	8.18	197.0	211.0	21.0	120.0	190.0	11.50
900	23	92.2	211.0	9.83	259.0	261.0	33.9	137.0	224.0	15.51
					5-inch pipe					
1,000	25	96.2	230.0	11.1	85.4	227.0	9.8	159.0	269.0	21.4
1,100	28	102.0	260.0	13.4	87.1	254.0	11.2	186.0	297.0	27.9
1,200	30	108.0	281.0	15.4	88.6	274.0	12.3	228.0	327.0	37.6
								6-inch pipe		
1,200	30	----	----	----	----	----	----	83.7	272.0	11.5
1,400	35	124.0	335.0	21.0	93.2	320.0	15.0	85.3	318.0	13.7
1,600	40	147.0	395.0	29.3	99.9	370.0	18.5	87.4	364.0	16.1
1,800	45	178.0	463.0	41.6	108.0	421.0	23.0	90.6	410.0	18.8
2,000	50	----	----	----	119.0	475.0	28.6	93.8	458.0	21.7

TABLE 9.—*Number of sprinklers, head, gallonage, and approximate horsepower (50-percent efficiency basis) necessary for portable sprinkler pipes of specified lengths, carrying sprinklers with a capacity of 15 g. p. m. at 45 pounds per square inch when pressure at most distant nozzle is 45 pounds*

[For sprinkler pipes only—does not include rest of system]

Length (feet)	Sprinklers	Head	Quantity per minute	Horsepower	Head	Quantity per minute	Horsepower	Head	Quantity per minute	Horsepower
	Number	*Feet*	*Gallons*		*Feet*	*Gallons*		*Feet*	*Gallons*	
		2-inch pipe								
120	3	108	45.2	2.46	---	---	---	---	---	---
140	4	110	60.4	3.36	---	---	---	---	---	---
					2½-inch pipe					
180	5	116	76.0	4.46				---	---	---
								3-inch pipe		
200	5	119	76.3	4.56	108	75.8	4.18			
300	8	151	127.0	9.64	118	122.0	7.28	109	121	6.64
400	10	229	172.0	19.92	133	155.0	10.42	114	152	8.76
500	13	---	---	---	164	209.0	17.32	125	199	12.60
		4-inch pipe								
600	15	111	226.0	13.9	213	254.0	27.34	142	235	16.86
700	18	116	274.0	16.1	281	324.0	46.02	159	288	23.1
					5-inch pipe					
800	20	122	306.0	18.9	109	301.0	16.6	189	329	31.4
900	23	130	355.0	23.3	112	348.0	19.7	232	397	46.6
								6-inch pipe		
1,000	25	139	391.0	27.5	113	378.0	21.6	108	376	20.6
1,100	28	151	443.0	33.8	117	427.0	25.3	109	423	23.3
1,200	30	164	481.0	40.0	122	460.0	28.5	110	453	25.2
1,400	35	---	---	---	133	543.0	36.5	114	532	30.6
1,600	40	---	---	---	147	628.0	46.6	120	611	37.0
1,800	45	---	---	---	---	---	---	126	695	44.4
2,000	50	---	---	---	---	---	---	134	777	52.6

While tables 8 and 9 are approximate only and subject to variation for every different make and type of sprinkler and its operating characteristics, or the quantity of water handled at the stated pressure, and for every change in the efficiency of the pumping outfit, it does show the desirability of using large enough pipe and reasonably short laterals. The consumption of power increases rapidly after the pipe lines reach a certain length. Power consumed in operation is of course continual expense when the outfit is running. Although the power requirement can always be reduced by increasing the size of the pipe this means added investment cost. Even where investment cost is not a prime consideration, it is not always feasible to increase the size of portable pipes because so doing may unduly increase the difficulty involved in moving them.

The engine or motor power commonly allowed for supplying the larger systems often runs as high as 1 to 1½ horsepower or more per

acre irrigated; for instance, a 100-horsepower engine for a 60-acre tract. This horsepower allowance seems high and is undoubtedly related to extra friction losses due to using unduly long laterals. With small systems, satisfactory irrigation may be secured with as little as one-half horsepower per acre, say a 5-horsepower engine for a 10-acre tract.

Overhead-Pipe System

The overhead-pipe system of sprinkling irrigation (fig. 26, *A*) is generally permanently installed. As compared with sprinkling from light, portable pipes discussed in the previous section, the overhead-pipe system has the advantage that it can be operated with very little labor—simply turning on and off valves if the system is fully equipped with permanently installed automatic oscillators. It has the same advantage as the previously discussed system in that it may be used on any tract of land without grading. It is economical of water, and very uniform distribution is attainable. It is, however, expensive to install, and the upright pipes are obstructions to cultivation though farmers do not object to them when they become accustomed to them.

The basis of this system of irrigation is a perforated pipe, supported at a suitable height above ground, that may be turned or rotated in its supports. The perforated pipe must be connected to a piping system that can furnish water under suitable pressure. The perforations are lined with nonrusting nozzles that direct the flow of water perpendicularly to the pipe line. All streams emerge parallel and point away from the ground at the same angle when they leave the perforated pipe.

The nozzles in the overhead, perforated pipe are all in one plane at intervals of 3 to 4 feet. Measurements indicate that 100 nozzles of the size and make commonly used will discharge approximately 13 gallons per minute under 10 pounds pressure, 18 gallons per minute at 20 pounds, 22 gallons per minute at 30 pounds, and 25 gallons per minute at 40 pounds. Under suitable pressure such a system will irrigate a strip 25 feet wide on both sides of the pipe line, or a total width of 50 feet.

Overhead-pipe systems may be purchased on a contract basis in which the entire system is completely installed by the contractor. More commonly, however, the irrigator does some part of the work himself. A common practice is for him to buy the sprinkler-pipe lines drilled and tapped for the nozzles and equipped with the proper fittings, and to install the pumping equipment, the main and riser pipes, and the supporting posts. Many farmers install the complete system themselves, even to drilling and tapping the nozzle lines. If the installation is planned well in advance, parts can be installed when other field work cannot be done.

When threaded-joint pipe is being assembled for any part of the system, heavy graphite grease should be applied to each joint after one or two turns have been made in screwing the pipe together. White lead should not be used where it may get inside the pipe and clog the nozzles.

Most of the smaller pipe used will be put together with threaded joints, and therefore fittings for connection to threaded pipe should be provided in a large welded pipe line wherever connection with

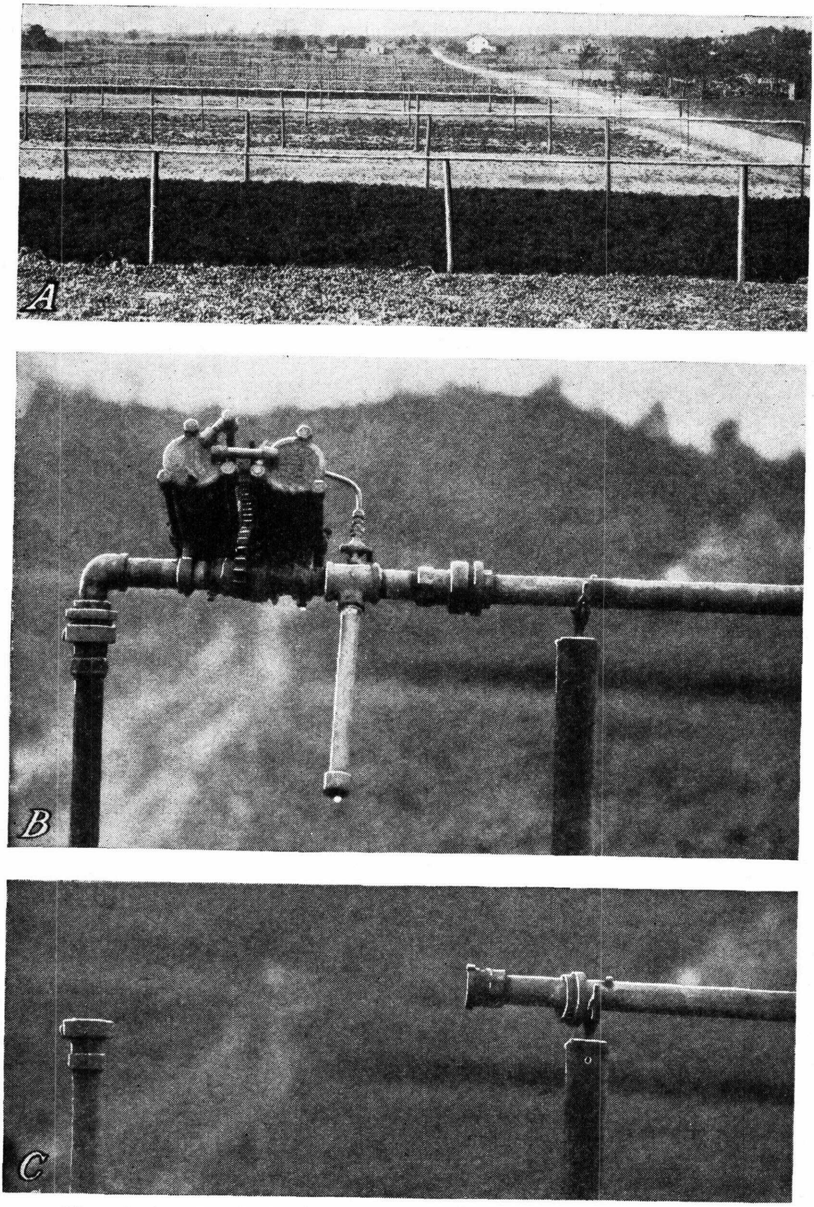

FIGURE 26.—*A*, Overhead-pipe sprinkling equipment on several adjoining fields of different farms; *B*, portable oscillator in place, and *C*, removed.

smaller-sized pipe is to be made. Threaded-joint pipe will ordinarily be used above ground. If poured-lead joints are used in cast-iron pipe, they can also be used to connect a special cast-iron fitting suitably tapped for connection to threaded pipe. For the riser pipes this usually means installing in the main a cast-iron tee with a threaded side outlet.

After the main distribution line is laid, the upright pipes or risers that supply the overhead lateral nozzle lines, cut to the right length and threaded to receive the fittings that will go on top, should be screwed into the tees or connection fittings in the main. If convenient, these uprights or risers may be fully assembled before being screwed into the main. The upright should not be smaller than the largest pipe in the lateral, and one size larger is the rule. Where one riser pipe will simultaneously feed two laterals, one on each side of the main, it should be large enough to supply both lines at once.

The overhead laterals are commonly set at a height of 4 to 5 feet and are supported by wood or metal posts. The upright pipe serves as the first one. The posts should be carefully lined up from both directions. It is best to place the outside posts around the field first; then the interior ones can be lined up with them. The posts are usually placed 12 to 15 feet apart along the nozzle lines, which requires 73 to 58 posts per acre for lines 50 feet apart.

If the supports are of wood, 4-inch posts are generally used. The lower ends of the posts, up to about 6 inches above the ground, should be treated with wood preservative or painted with tar or creosote before they are set in the ground. After being properly placed, the posts are cut off either at a uniform elevation for each lateral or at a uniform height from the ground. Either way will give a good appearance to the field.

Steel pipes 1 inch or larger in diameter make good supports. Six-inch post holes are dug about 2 feet deep and the pipes are driven down sufficiently to bring the top to the required height. If 1-inch pipe posts are being installed, the hole is filled with concrete. About three-fourths of a cubic yard of concrete is required for setting 50 posts in 6-inch holes 2 feet deep. For this quantity of 1:2:4 concrete, 5 bags of cement, 0.4 cubic yard of sand, and 0.7 cubic yard of gravel or stone will be ample. Larger posts may be set without concrete.

At its connection to the riser pipe, the sprinkler pipe must have capacity to supply the entire line without loss of pressure. The pipe size may be reduced gradually to a minimum of three-fourths of an inch at the end. The sizes in general use that have proved satisfactory are shown in table 10.

Steel pipe with threaded joints is ordinarily purchased in lengths of nominally 20 feet. In assembling a pipe line it is customary to assemble the large pipe first, and to cut only the ¾-inch pipe in the field. No nozzle-pipe line should be longer than 700 feet. If lines longer than 500 feet seem to be necessary, it is desirable to redesign the system or at least to install an additional main or submain to shorten the nozzle-line lengths. Where automatic oscillation is intended, no lines longer than 450 feet should be used, and shorter lines are desirable.

Galvanized pipes should always be used not only because they are more durable than ungalvanized or black pipe but also because much less rust scale, which is liable to clog the nozzles, is likely to form in them. The fittings, such as tees, elbows, reducers, bushings, and caps, are made of the more durable malleable or cast iron and do not need to be galvanized. Galvanized fittings are, however, generally preferred because of appearances.

TABLE 10.—*Lengths of different sizes of pipe for sprinkling laterals of designated lengths: 3- and 4-foot nozzle spacings* [1]

3-FOOT NOZZLE SPACING

Length of line (feet)	Length of—				
	2-inch pipe	1½-inch pipe	1¼-inch pipe	1-inch pipe	¾-inch pipe
	Feet	*Feet*	*Feet*	*Feet*	*Feet*
100				20	80
150				80	70
200				120	80
250			80	100	70
300			140	100	60
400		120	120	100	60
500	100	120	120	100	60
600	200	120	120	100	60

4-FOOT NOZZLE SPACING

Length of line (feet)	2-inch pipe	1½-inch pipe	1¼-inch pipe	1-inch pipe	¾-inch pipe
100					100
150				60	90
200				100	100
250				160	90
300			60	160	80
400			160	160	80
500		80	180	160	80
600		180	180	160	80
700	100	180	180	160	80

[1] Pipe is ordinarily bought in lengths of approximately 20 feet, threaded at both ends. The labor of cutting and fitting is least when full lengths are used, and only the smallest size (¾-inch) will need to be cut for any nozzle line.

All dirt and scraps of metal should be carefully removed from each section of the sprinkler pipe before it is put together and the joints screwed tight.

If the nozzle lines are not bought complete, the pipe should be drilled and tapped for the nozzles with a special machine made for the purpose. This machine drills the holes in a straight line along the pipe. It hangs from the pipe and drills in the lower side of it. Lard oil or screw-cutting oil should be dropped on the upper side of the pipe where it can run down into the drill and lubricate it. The assembled pipe line should be supported about 4 feet above the ground. If posts of this height are being used for supports, the pipe can be drilled in place. If higher, wooden posts are used, the pipe can be supported for drilling on heavy spikes driven into the posts at a height of 4 feet. The pipe can be supported from steel posts by loops of wire at each post. If very low posts are used, enough portable temporary supports for one pipe line should be provided for the drilling process and moved from line to line as drilling progresses.

The pipe line must be fastened against turning while being drilled. This is best done by putting an elbow temporarily but tightly on the end of the pipe line and screwing into it a short piece of pipe that can be fastened to a stake in the ground. The nozzle-hole locations are then spaced with a stick and marked with a crayon.

All overhead-sprinkler lines must be equipped with some means of rotating or turning the pipes. Many pipes are rotated by hand, by means of a bar or short pipe attached to a turning union—a device that permits the pipe attached to one side of it to be rotated while the pipe

on the other side remains stationary. These hand-operated lines should be turned a little every 10 to 15 minutes while water is flowing. In many of the more recent installations oscillators operated by a part of the water in the pipe are used to rotate the lines. These automatic oscillators, or line turners, reduce the attention necessary when irrigating. Many pipes that were originally rotated by hand are now being equipped with automatic turners. Since installation of oscillators in every sprinkler pipe is expensive, many growers use portable oscillators. Figure 26, *B*, shows the upper end of a riser pipe and the end of a rotatable nozzle pipe with the portable oscillator and attendant fittings installed; in figure 26, *C* the same riser pipe and nozzle line are shown with the portable oscillator removed. The secret of satisfactory operation with portable oscillators is ready means for installing and removing the portable equipment. The couplings illustrated permit attaching and removing the portable assembly without the use of tools.

Turning unions are often provided with an internal screen for catching scale or sediment that might clog the nozzles. Thoroughly effective screening at the pump intake is much to be preferred, although, of course, it cannot eliminate the clogging of nozzles due to scale originating in the piping system.

Suitable means must be provided for keeping the laterals in place on top of the supporting posts. If automatic oscillators are used, the lateral is generally held in place by means of special hangers of the bar or roller-bearing type. The roller-bearing hangers should be of nonrusting and noncorroding material. For hand-turned lines simpler devices may be used. A stout nail may be driven each side of the pipe in the top of wooden posts; nails may be driven into wooden or concrete plugs in the top of large-diameter pipe posts; wooden blocks that have specially shaped grooves to fit the sprinkler pipes may be inserted in pipe posts. By frequent lubrication some of these simpler types can be used with automatic oscillators if the laterals are not longer than 125 feet.

Since iron chips get into the line during tapping the entire piping system should be thoroughly flushed out before the nozzles are screwed into place. The caps on the ends of the nozzle lines are removed, or the flushing valves are opened, and a strong flow of water is pumped through each line. The nozzles are put in and the system is ready for use.

Covering the main pipes in the trenches is usually the last step of constructing any irrigation system. It is well to start the pump before doing this, in order that that line may be tested under pressure and any leaks in the line seen and repaired.

A single lateral, or nozzle-pipe line, is sufficient for irrigating many home gardens. For larger tracts laterals are installed in parallel positions, commonly at 50-foot intervals. Forty-eight feet would give better distribution at the pressures in common use, which range from about 20 to 40 pounds at the nozzles. For large fields it is sometimes economical to widen the spacing to 55 feet and increase the pressure to 60 pounds at the nozzles. With properly selected nozzles good distribution of the irrigation water over the space between the laterals may be secured. Figure 27 shows the connections

for two laterals fed from risers at the sides of a separating roadway. Along one side of the roadway runs the underground main pipe that supplies the series of sprinkler pipes.

It is desirable that the nozzle lines have the same general direction as the crop rows. Long nozzle lines and short mains cost less for pipe and fittings, but a larger number of short nozzle lines make possible the irrigation of small parts of the field at one time. For a field of 2 to 3 acres it is common to lay the main along one of the longer sides and run the nozzle lines across the field at right angles to the main.

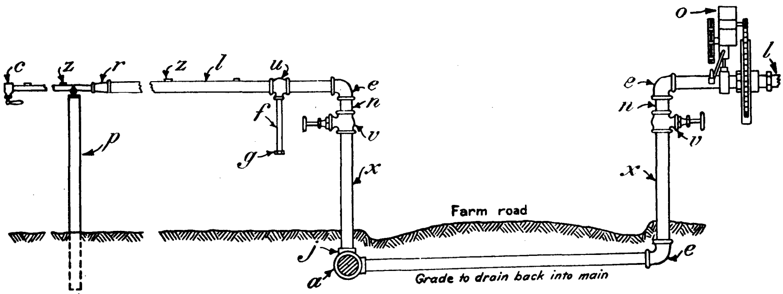

FIGURE 27—Typical fittings for overhead-nozzle laterals, showing equipment for hand-turned lines at the left and for automatically turned lines at the right of the road: *a*, Underground main; *j*, tee (the one shown has a side opening, used only for connecting beneath the road to another nozzle line); *x*, upright; *v*, valve; *n*, nipple; *e*, elbow; *u*, turning union; *f*, pipe handle for turning line; *g*, cap on handle; *l*, nozzle line; *z*, nozzles of rustproof and corrosion-proof metal; *r*, reducer connection to smaller pipe; *c*, cap or flushing cock; *p*, post support for lines; *o*, turn motor, or oscillator.

Although permanent installations are the rule with this type of irrigation many irrigators install permanent main and riser pipes and portable laterals, and change to permanent laterals as finances make it possible. To move portable laterals, either the whole line must be moved as a unit, which requires a force of men, or the line must be divided into sections. To make the reassembling of these sections easy, particularly the alinement of the nozzles, special quick-acting couplings or unions are made with a square or hexagonal projection or other suitable arrangement on one end of the pipe that fits into a recess of the same shape in the next pipe.

Three-quarters to one and one-half horsepower per acre of land under pipes is common for driving the pump for this type of sprinkling irrigation, although with well-selected equipment less horsepower may be used.

Other Sprinkler Systems

Perforated Slip-Joint Pipe

Galvanized, lightweight pipe that is perforated along its top so as to permit small streams of water to spray on both sides of the pipe makes a satisfactory low-pressure sprinkler pipe. Three-, four-, and five-inch diameter pipe joined by slip joints—the tapered end of one piece of pipe shoved into the end of the adjoining pipe—are commonly

used for the sprinkling laterals. In assembling this kind of pipe the joints are generally tightened by a hammer blow struck on a plank held across the end of the newly added piece. Laterals are from 200 to 500 feet or more in length. Low pressures, ranging from 4 pounds up to perhaps 15 pounds per square inch are used. Under 15 pounds pressure, if conditions are favorable, a strip of ground 30 feet wide or more (15 feet each side of the pipe) may be wetted at one setting.

Eyelet Hose

Eyelet hose is made of waterproofed canvas cloth and has eyelets at frequent intervals along its length. It is now most widely used in orchard irrigation where the soils are sandy (fig. 28). Under low

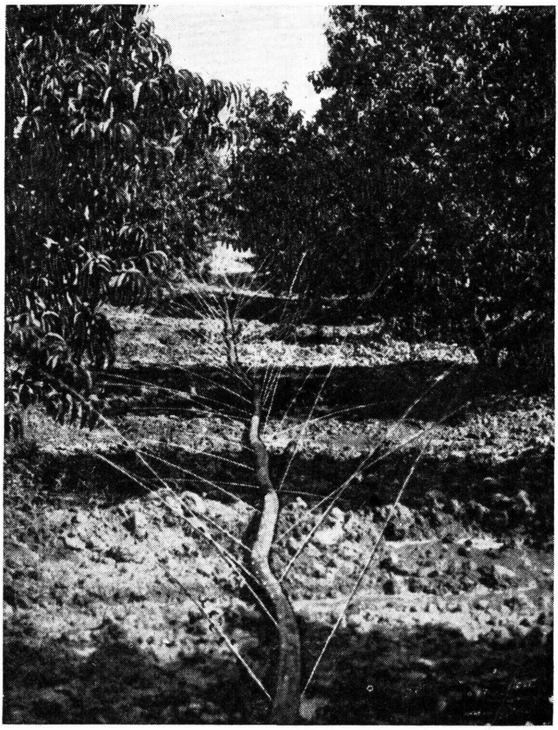

FIGURE 28.—Irrigating an orchard with eyelet hose.

pressure, 5 to 8 pounds per square inch, it will sprinkle some 6 to 8 feet on either side and therefore irrigates rather effectively one middle at one setting in an orchard with the tree rows planted at 20-foot intervals. Under greater pressure it will sprinkle a wider strip. It is readily portable, and its first cost is not great; however, it probably is very short-lived. The period of its use has been too short to determine the rate of depreciation. Commonly it is about 2¾ to 3 inches in diameter and is made up in 200-foot lengths, with four small eyelets around the circumference at intervals of 2 feet. No matter how

eyelet hose may lie, at least two—usually three—outlets are open every 2 feet for the free discharge of water. Each end of each length is equipped with a threaded brass fitting for connection to another length of hose or to a threaded iron supply pipe. Four hundred feet is apparently a satisfactory operating length. The hose should be emptied before it is moved. It may be rolled or gathered loosely for carrying to the next irrigating position.

Under ordinary conditions eyelet hose with 4 openings one-sixteenth inch in diameter every 2 feet may be expected to discharge for each 100 feet of hose about 40 gallons per minute under a head of 6 feet, and perhaps 1½ times as much under a head of 12 feet. It is possible to increase the discharge somewhat by using a higher head, but the lower the head is kept, the less quickly will the hose burst when the fibers become weakened with age.

Frost Protection

Sprinkling irrigation gives some frost protection, but this value of an irrigation system is not well understood. It is probably primarily in extending the autumn season through one or two cold nights that may be followed by several warm days, or in protecting an early crop through an unseasonable spring frost. Reports of successful protection and unsuccessful efforts seem to be about equally frequent. Too much protection must not be expected—from not more than a few degrees of frost and of only a few hours' duration. Protection through a long period of very low temperature cannot be hoped for and further, in too long a cold spell, even if of only moderate intensity, the possible damage from broken stems and branches due to the accumulating ice load may be as harmful as the possible frost damage.

Protection is obtainable only on the area that can be watered at one time, whether limited by the amount of water that can be pumped or by the amount of equipment available, if the system is portable, and only by starting sprinkling before the temperature gets to the freezing point. The thermometers being used must be accurate. *After sprinkling is started, it must not be stopped until increasing natural warmth has again brought the temperature up to a safe point.* If ice forms on the plants, the sprinklers must be kept running until all the ice has melted. The presence of ice indicates that the plants have reached a temperature of 32° F. It does not mean that the plants are killed; continuing to supply water may keep the temperature of the foliage from dropping below 32°. Shutting off the sprinkler while the plants are encased in ice will kill them.

LOW-PRESSURE OOZING

Porous canvas hose, from which the water slowly oozes through the interstices between the threads of the canvas, is used for irrigating to some extent. This method of irrigating has advantages where the ground surface is only slightly irregular, and also where the soil is too sandy for satisfactory furrow irrigation. The method may be used where the knolls and ridges do not exceed perhaps 2 feet above the lowest point that the hose may cross on the supply side of any particular ridge. It works best, however, where there is a slight and regular fall from the supply end of the hose to the far end, which is closed. Only a narrow strip, perhaps 2 to 3 feet wide, depending on soil conditions, is watered from one position of the hose, but the hose

may be placed in many positions while still attached to one hydrant. In irrigating row crops such as strawberries, potatoes, and other crops that do not grow too high, a pulley-wheel device can be used which, when carried down the field, will lift the hose over the plant row from one middle to the next (fig. 29).

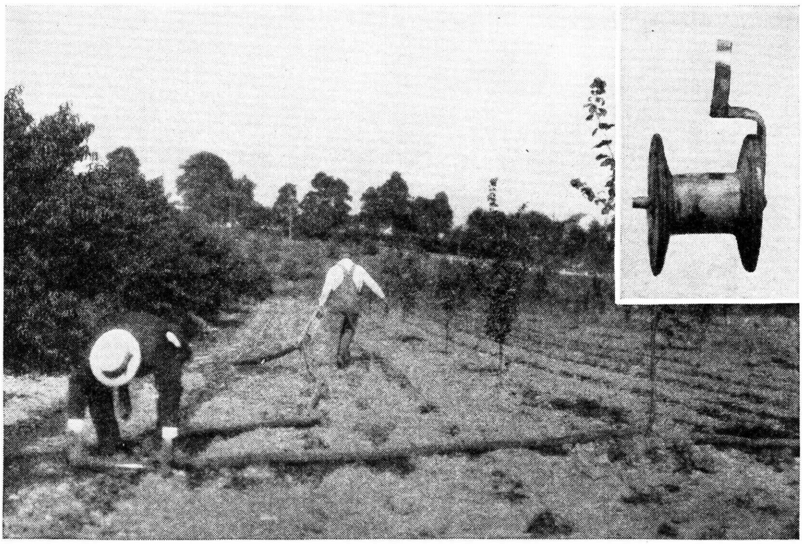

FIGURE 29.—Porous canvas hose being used to irrigate strawberry plants. (Inset: A pulley device for lifting the hose over the plant row.)

There is a patent on porous hose, which has now been assigned to the Michigan State Board of Agriculture. Porous hose is commonly made from 8- to 12-ounce canvas cloth in 50-foot and 100-foot lengths. Hose with a diameter of about 2¾ to 3 inches is most common, although larger and smaller diameters are used. Irrigating lengths up to 600 feet have been found satisfactory. In assembling some lengths it is desirable to use hose of different weights to help equalize the rate of seepage in the different parts. The heavier hose is used where the pressure is greatest, ordinarily near the pump and in the low places. Three types of joints are used: (1) A specially manufactured stainless metal-end fitting by means of which one length of hose is attached to another by a simple twist; (2) a short-length metal tube inserted in the ends of the two pieces of hose and fastened in place by winding wire tightly around outside the hose ends; and (3) a joint made by simply shoving one end of one hose about 18 inches to 2 feet into the end of the other and pinning it with a nail, a wire, or sometimes a safety pin.

Relatively low pressures are used in this type of irrigation. Lightweight hose will begin to seep under a pressure head of 2½ to 3 feet, and pressures of more than 7 pounds per square inch (16.2 feet of head) on the hose are seldom, if ever, used. Because of frictional resistance in the pipes supplying the hose, higher pressures will, of course, be necessary at the pump. A valve in the supply pipe near the hose connection is desirable. This makes it possible to regulate to some extent the pressure in the hose and the rate of seepage.

The quantity of water required to supply porous canvas hose varies, depending on the condition of the hose and the absorptive

capacity of the soil. Under test, different kinds of relatively new hose, 2½ to 3 inches in diameter, when well wetted, have seeped water at the rates per 50 feet of length per minute shown in table 11.

TABLE 11.—*Seepage rates of different kinds of hose*

Head (feet)	Kind of hose		
	8-ounce untreated	12-ounce untreated	8-ounce fibers waterproofed
	G. p. m.	*G. p. m.*	*G. p. m.*
7	19	1½	8
6	13	1¼	5
5	8	1	3
4	4	⅔	1½
3	2½	⅓	1

The time required to apply 1 inch of water from any one position of the hose depends on the pump capacity, the length of hose line, and the width of the strip being watered. If the quantity of water delivered by the pump is 10 gallons per minute per 100 feet of hose, the time required to deliver 1 inch of water is as follows: If the hose is moved sideways at one time (commonly one row) 2 feet, it should remain 12 minutes; 2½ feet, 16 minutes; 3 feet, 19 minutes. Or the time may be computed as follows:

$$\text{Number of minutes} = 0.623 \times \frac{(\text{Number of feet hose is moved sidewise}) \times (\text{length of watered row in feet})}{\text{Number of gallons per minute of water supplied}}.$$

Irrigating with porous hose is laborious. About 1,200 feet of hose is ordinarily all that one man can attend to. The hose should be in three 400-foot lengths or two 600-foot lengths or in shorter lengths. Canvas-hose equipment, however, is one of the cheaper types of irrigation equipment, in spite of its relatively short useful life. Length of use will vary with climatic and service conditions and with the care exercised in storing the hose when not in use. Probably 1½ to 3 years' use is about all that may be expected from untreated hose, with a longer period for hose the fibers of which are waterproofed. The hose should never be left lying in a muddy field.

It is possible to irrigate some home gardens at very small expense by means of porous hose attached to the domestic water-supply system. Porous hose is very economical in its use of water, and the pressure required is small.

SURFACE IRRIGATION

Wherever the slopes are favorable, surface irrigation can be installed at relatively small expense. Except for the irrigation of rice and cranberries, which are more or less special, furrow irrigation is the commonest form of surface irrigation in the territory under consideration.

A few alfalfa fields are irrigated by canvas conveyor hose or other portable-pipe system, and basin irrigation has been reported, but the other types of irrigation common to the arid section are not being used in the humid region to any great extent. This is probably

because maintaining the necessary structures during the wet years would be unduly burdensome.

The quantity of water required per acre for surface irrigation depends on the soil of the field to be irrigated but is generally more than is necessary for the other types of irrigation discussed so far. Although more water has to be pumped, the pressure against which it must be pumped is often so much less that no more power is required. Generally 1½ inches depth is the least that can be used to give a thorough irrigation on a heavy soil that has not been allowed to get unduly dry. From that minimum the quantity increases with changes in soil types to 3 to 4 inches for a thorough irrigation on very sandy soil.

Furrows

Furrow irrigation is adaptable to tracts that have very gentle slopes, 1 to 12 inches per 100 feet or preferably 2 to 4 inches, in one direction only. A sufficient water supply must be available, preferably gravity water. It is most suitable for crops that are normally grown under methods of cultivation that tend to depress the middles between rows and to raise the earth along the rows. Ditches to supply the water to the furrows may be 400 to even 1,000 feet apart if the soil is heavy, but they should be fairly close together, not more than 300 feet apart, if the soil is reasonably porous. Runs as short as 200 feet are often desirable.

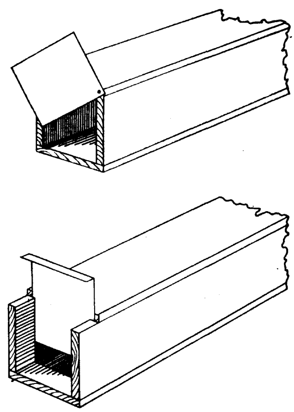

FIGURE 30.—Spout box for ditch or bank.

The precise quantities of water necessary are not so definite as for sprinkling irrigation. Table 1 (p. 4) indicates how much should be provided. Less than 100 gallons probably cannot be handled with economy, although smaller quantities may be acceptable for irrigation of a small home garden where financial profits are not required.

From the supply ditch, water should be diverted into a short head or manifold ditch arranged to supply several furrows simultaneously, by an opening dug in the side of the ditch, by more permament spout boxes (fig. 30), or by simple wooden gates. To distribute the water in the furrows, wooden shingles or pieces of tin or galvanized metal may be stuck into the sides. Short lengths of pipes or small wooden spout boxes are sometimes used.

In many systems water is brought to the furrows or to the head ditch that directly feeds them by pipes instead of supply ditches. In some systems the head ditch is replaced by a trough with notches cut in the side (fig. 31, *A*). Some furrows are supplied by means of light-weight galvanized pipe with small openings at suitable points, which may be closed by means of adjustable sliding gates. Other common methods are to discharge water from a hose into the high end of a furrow and move the hose when enough water has been discharged (fig. 31, *B*), and to discharge water from a hose at a point

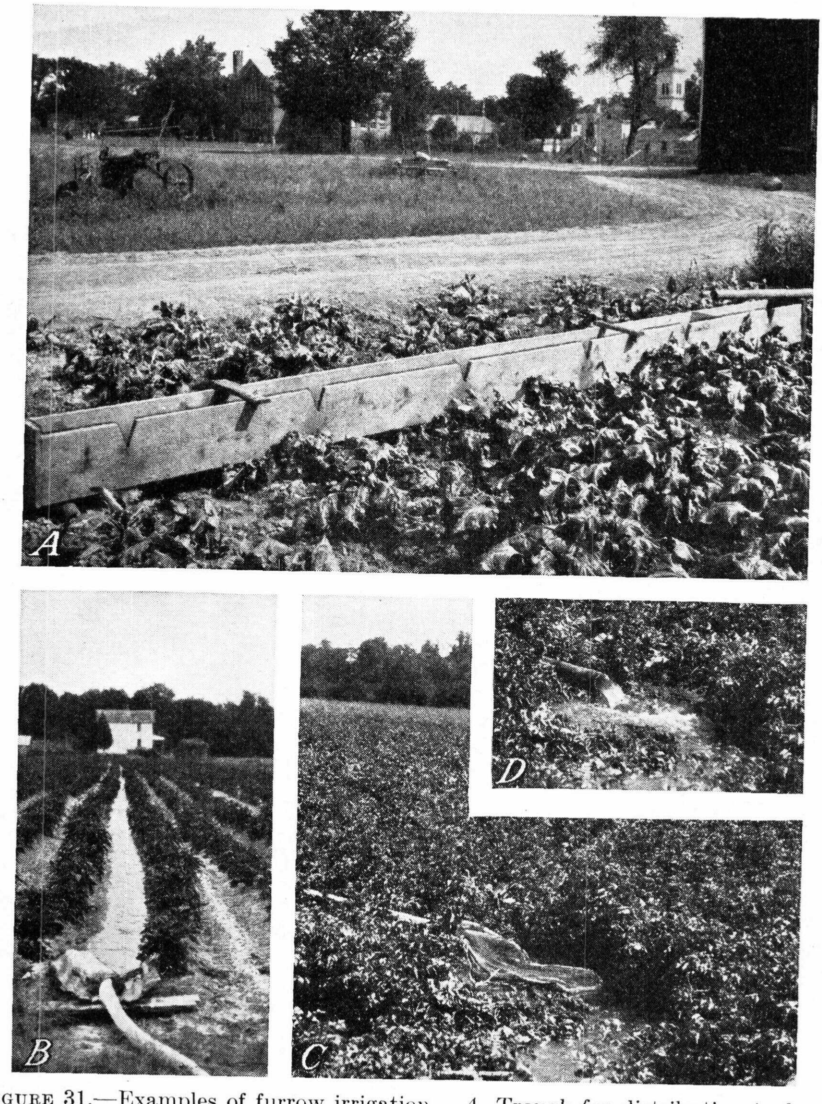

FIGURE 31.—Examples of furrow irrigation. *A*, Trough for distribution to furrows. *B*, Irrigating peppers one furrow at a time. *C*, Irrigating potatoes by letting water spread over several furrows at one time. The sack is used to prevent erosion at the point where the water is discharged. *D*, The stream of water when the sack is removed. Rain-conductor pipe is being used at the end of the hose.

where it may wet several furrows (fig. 31, *C* and *D*). Frequently condemned fire hose that is serviceable for farm irrigation may be purchased at a low price. Home-made canvas hose 2 to 8 inches in diameter may also be used.

Usually water should be let into each furrow and made to reach the lower end as quickly as possible; the quantity entering each furrow can then be decreased as necessary, although the regulation should be such that a sufficient supply will always reach the end of the furrow.

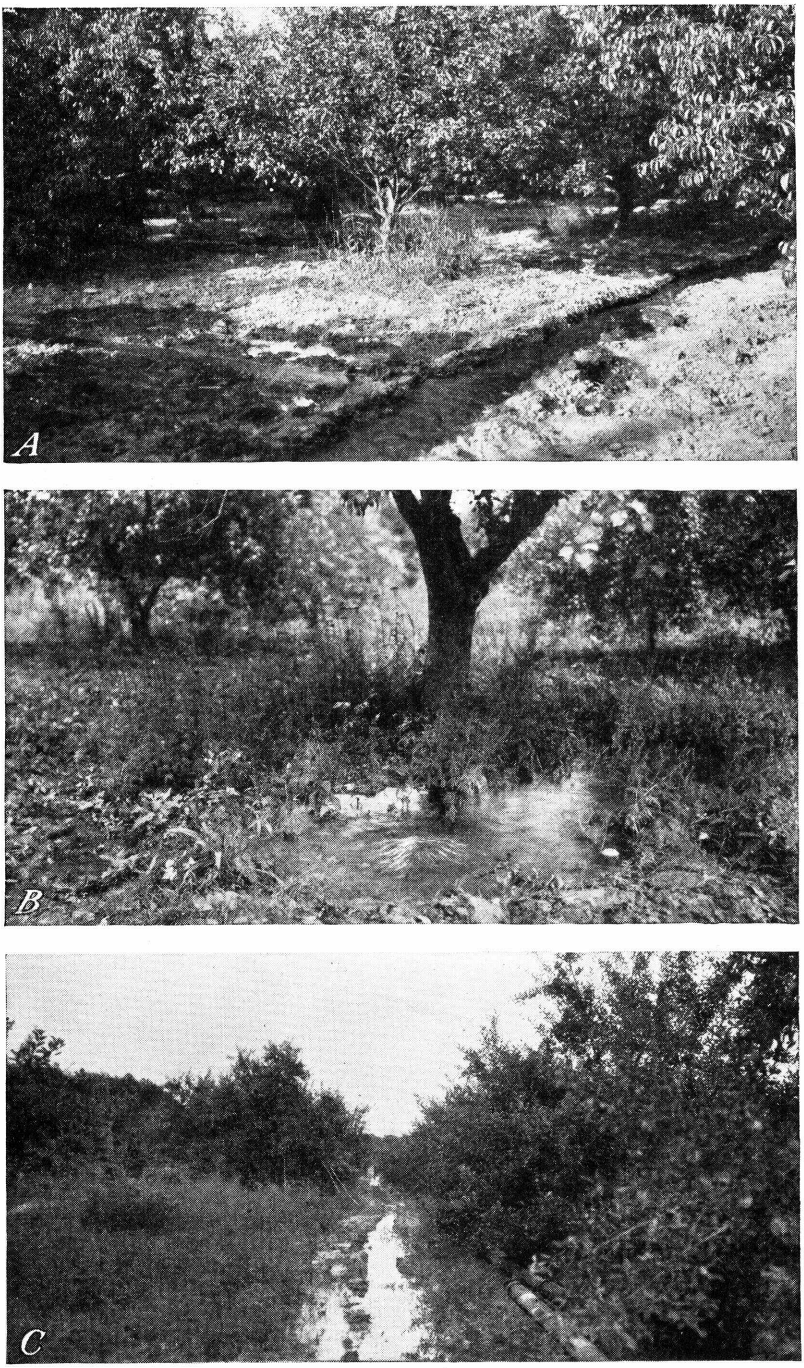

FIGURE 32.—Orchard irrigation: *A*, By furrows; *B*, from a low-pressure sewer-pipe outlet; *C*, from a trench prepared for a future pipe line.

Waste at the lower end should, however, be avoided. In general, for sandy soils use a large stream run for a relatively short time. For clay soils use a small stream run for a longer time. Whether the water has run long enough may be determined by digging at several points along a row. If the soil below the root zone is moist, water is being wasted. It is best not to wet the surface of the ground in the row of the plants, but to allow the water to seep into the soil from furrows or middles between the rows. This will prevent the soil in the rows from baking and cracking later.

Orchards may be irrigated by furrows. The most common practice is to run the water down the middles between the trees. Some irrigators put in two or more special furrows to spread the water out more widely over the middles between the trees. Three examples of the irrigation of apple orchard are shown in figure 32.

Other Surface Methods

Outside the Rice and Cranberry Belts, methods of surface irrigation other than that with furrows are seldom used and, if used, almost every one is adopted for a special reason.

Basin Irrigation

Basin irrigation is the accepted method for irrigating rice and cranberries. There is justification for its somewhat wider use. Basin irrigation is a kind of flooding. Water is applied to approximately level plots that are made into ponds, or basins, by surrounding them with ridges of earth.

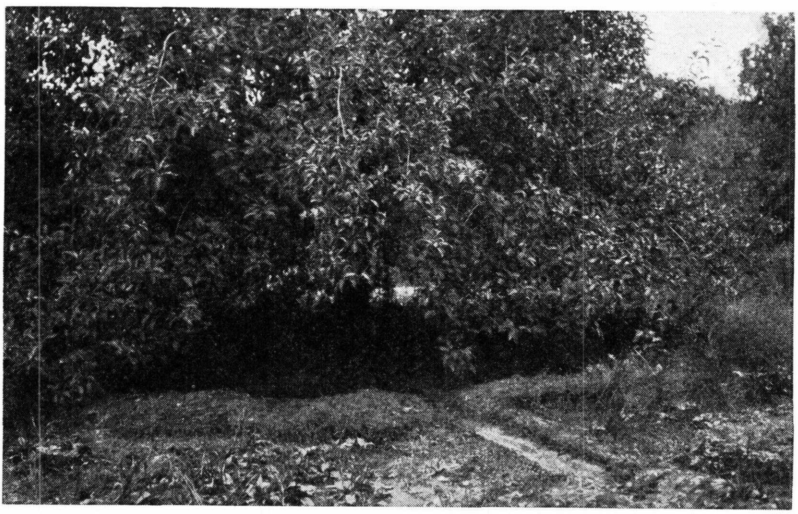

FIGURE 33.—Basin used in orchard irrigation.

Basin and furrow irrigation were used together in an interesting manner in an orchard where the trees had originally been planted on mounds. Because of the mounds it was a problem to get much water to the big mass of roots near the trunks of the trees. Doing this was

further complicated by sloping ground in part of the orchard. The problem was solved by making basins around the trees with a California orchard cultivator especially altered for this purpose. The outfit, dragged three or four times around the tree by means of a tractor, threw up a ridge forming around the trunk an approximately circular basin about equivalent in circumference to that of the drip line of the tree (fig. 33). On the more steeply sloping part of the orchard it was impossible to get water to the soil on all sides of the tree by merely allowing the water to be ponded by the circular ridges, or levees, and across many of the basins it was necessary to put in one or sometimes two levees (fig. 34). When any basin had become filled, a cut was made in the levee to let water down to the next basin. The water set free by opening the levee was permitted to run down to the next basin or part basin and fill that. It was sometimes necessary to dig a shallow shovel ditch to guide the water from tree to tree, and sometimes it was necessary to construct little levees to make the water follow the desired course to the next basin.

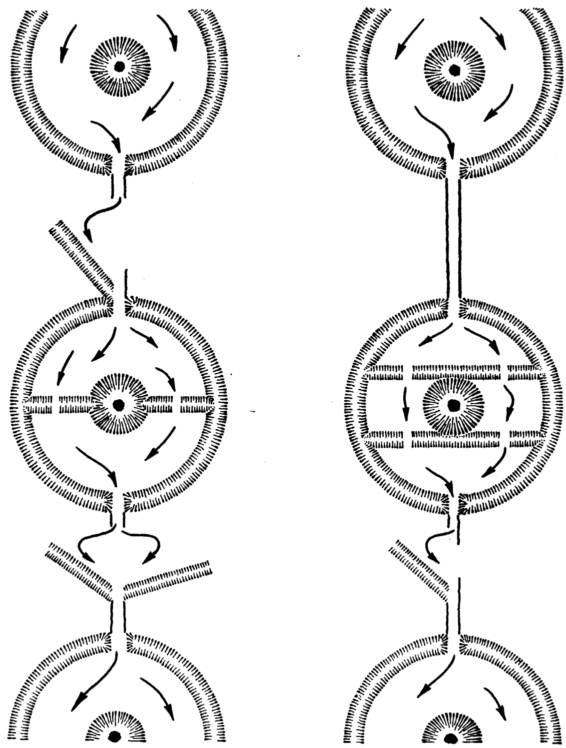

FIGURE 34.—Basin irrigation with incidental levees.

Portable Conveyor Pipe

Portable conveyor pipe is convenient for irrigating plants such as alfalfa and low-growing vegetable crops and grass wherever water under very low head is naturally available and the land is too sandy or the slopes, though slight, are not suited to furrow irrigation. It is also adapted to the irrigation of orchards. Because it can be operated under low head, its use is desirable in many places even where water has to be pumped. The designation "conveyor" is used to distinguish it from portable sprinkler pipe. The water is commonly turned loose from the open end of the assembled conveyor pipe.

Either portable pipe with quick-assembling and -disassembling joints, now used for the newer type of portable sprinkling irrigation, or the

older portable slip-joint pipe is suitable. Lightweight galvanized pipe is used, and short pipe lengths are preferred. Sixteen-foot lengths are acceptable in the former pipe. For slip-joint pipe 10-foot lengths are commonly used and the pipe should be made of 24- to 26-gage galvanized sheet iron for 6-inch and smaller sizes, and of 22- to 24-gage for 8- and 10-inch sizes. One end of each section should be slightly tapered so that it may be pushed into the untapered end of the following section to make a fairly tight joint. The ends should be reinforced with galvanized iron of not less than 18-gage; otherwise the seams may break when the sections are being connected or disconnected. Several firms make this pipe, and most local tinners can make it or order it. Some irrigators prefer the less durable but more easily obtained rain-conductor pipe. Most slip-joints, however, leak if water must be forced even a few inches up hill. This accounts in part for the increasing use of portable conveyor pipe with pressure-tight quick-assembling and -disassembling joints.

Portable pipes are generally connected with the supply hydrant by means of a 10-foot section of home-made canvas hose and a suitable, outlet hood. One end of this hose is connected to the hood discharge, generally by a tightly wound wire, and the other end is thrust into the nearest end of the portable pipe. Such a connection is quickly made and is very flexible.

Some tracts can be irrigated by laying the pipe along the highest side and letting water run down the slope. It is possible to lay the pipe on top of certain ridges and let the water irrigate both sides of the ridge. A special adaptation of pipe for furrow irrigation down such slopes is a pipe made with openings in the sides with valves or sliding gates to control the quantity of water discharged at each opening. Such openings are preferably spaced to suit the furrow spacings, usually 2½ to 4 feet.

The portable pipe may be built up, section by section, as irrigation proceeds, or the entire length may be built up first and the sections disconnected as necessary. As commonly used one pipe-length is moved every few minutes, usually about one-pipe length to one side, and is reassembled in a parallel position. Comparatively good distribution is secured over the area irrigated from each setting of the pipe, and the many settings make for good distribution over the irrigated tract. The labor necessary, because of the constant resetting of the pipes, sometimes makes this method more expensive than sprinkling irrigation in spite of the higher pumping and investment costs of the latter.

The portable pipes should be large enough to make the friction small. Only sufficient head to overcome friction in the length of the pipe plus enough static head to compensate for any rise in the ground surface is needed. For slip-joint pipe, which is ordinarily quite smooth inside, the friction-head data given in table 6 should be safe. For pipe with quick-assembling and -disassembling joints, the head necessary to cause flow may be greater since higher rises in surface elevation can be overcome and since somewhat smaller pipe may be used to transport the water. The friction data given in table 6 would be safe for use in establishing the water-carrying capacity of a line of this kind of portable pipe.

SUBSURFACE IRRIGATION

Subsurface irrigation, or subirrigation as it is commonly called, is excellent where it may be successfully used commercially. Since there are, however, very few such localities it is recommended that a test of the subirrigation possibility be made before any extensive outlay is made. The most favorable conditions for subirrigation are a level or gently sloping piece of ground with a porous topsoil underlain by an impervious layer and a copious supply of gravity water. A flowing well is the common source of water; for a very few systems the water is pumped. The impervious layer, clay or hardpan commonly, should be at a depth of 1½ to 2 feet for truck crops and 4 to 6 feet for orchards. Much water is needed because water must fill all interstices in the subsoil up to a certain level; capillarity is counted on only to a small extent. If there are openings through the impervious layer a large quantity of water is lost to deep percolation.

An inexpensive general test for the applicability of subirrigation to a certain tract is as follows: Level a small tract, approximately 20 by 30 feet, and dig an open ditch through the center. The ditch should be filled with water to within 6 inches of the surface of the ground and the water maintained at that level. This may be accomplished by placing a watertight barrel at one end of the ditch with a spigot in it to discharge the proper amount of water into the ditch. Unless moisture shows on the surface of the ground for a distance of at least 10 feet on each side of the ditch at the end of a 72-hour period and unless a small amount of water will keep the water level in the ditch up to the proper point, subirrigation will not be profitable.

Open-Ditch Systems

Subirrigation in its cheapest form may be found where a boundary ditch around a level 2- to 5-acre tract is the only equipment for distribution (fig. 35). This particular condition, which is very rare,

FIGURE 35.—Subirrigating a 5-acre tract from an open ditch. At the right is the flowing well that supplies the water. The picture was taken soon after the supply was shut off and the water has not yet disappeared from the basin formed by the well stream.

might not be revealed by the general test just referred to, because a limited amount of water would not be sufficient to maintain the water level in the ditch 6 inches below the ground surface. The question then would be whether the rapidly disappearing water was working sideways over the top of an impervious substratum, a condition favorable to subirrigation, or was percolating directly downwards, a common condition but hopeless for subirrigation. If a question of this kind

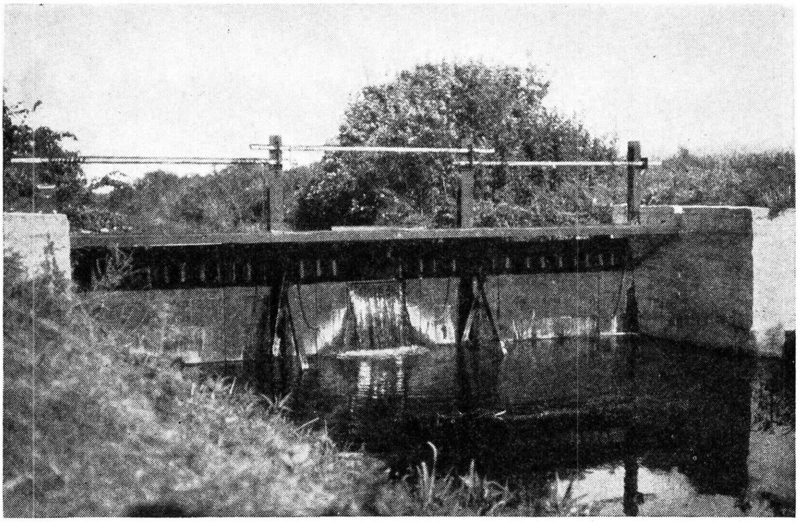

FIGURE 36.—Subirrigating a tract of muck land from a dam in a drainage channel. The gated dam backs up the drainage water in the channel and the water spreads out widely in the subsoil of the valley floor.

arises, the test with modification should be repeated after a couple of days. Before putting water into the ditch, six holes each about 5 to 6 inches in diameter should be made, preferably with a post-hole digger, three on each side of the ditch on a line perpendicular to the ditch near its center. These holes should be about 5 feet apart and should be deep enough to reach the impervious layer. Water depth should be measured in each hole frequently during the test. If water appears or the water level rises in these holes reasonably soon after water is put into the ditch, and if its advance from hole to hole as it gets farther away from the ditch may be noticed, apparently conditions are favorable.

The ditches that are used for subirrigation are also used for drainage when necessary. When it is desired to water the crop, the outlet is closed, and a stream of water is turned into the ditch, from which the water works its way laterally through the ground. The water seeping across the tract from the two sides, in the course of 30 to 72 hours, meets in the center, and the tract has been irrigated. The waste of water is great because a considerable area outside the tract is watered by outward seepage.

Water for subirrigating of the same general type is sometimes brought from a flowing stream. Figure 36 shows all the equipment that is necessary to irrigate a considerable area if conditions are favorable.

Pipe Systems

For the majority of the subirrigated lands, a systematic arrangement of parallel tile lines is necessary. These lines are commonly made up of 3-inch drain tile spaced 18 to 24 feet apart at a depth of 16 to 18 inches. The tiles are laid with uncemented joints as for drainage; in fact, here again, the same channels that distribute the water in irrigating are used for drainage when drainage is needed. Although a great deal of 3-inch drain tile has been used, 4-inch tile is probably to be preferred. Most lateral tile lines are supplied with water from a terra-cotta sewer-pipe main 4, 5, or 6 inches in diameter with tight, cemented joints. Suitable diversion boxes or stop pockets, as they are often called, are installed where each lateral joins the main. A short length of 2-inch steel pipe, cemented into a hole cut in the side of the stop pocket, is used in many installations to make the connection between the main supply pipe and the laterals. The flow of water into the laterals is controlled by a variety of arrangements in the stop pockets, the cheapest being gunny sacks and wooden plugs.

In the few tile lateral lines that run down the slope, additional stop pockets are generally installed at intervals of 100 to 400 feet. For drainage purposes the laterals may discharge into a main outlet pipe at their lower end. If the main supply pipe runs down the slope, it may also be used for the main drain when drainage is needed and the tile lateral may be run without grade and on the contours. This construction should be limited to small tracts. More commonly the laterals, although substantially following the contours, are given a grade of 1 to 3 inches per 100 feet. A second main is provided for drainage and is connected to the laterals at their lower end.

WHEN TO IRRIGATE

No precise rules can be set down as to when, and how long, to irrigate. The observant eastern farmer accustomed to watch the growth of his crops under the different moisture conditions imposed by nature is not likely to go far astray in judging when plants need moisture or when proper moisture conditions have been secured under his irrigation practice.

Most growers now approve the practice of giving a thorough irrigation when watering, and then they irrigate only when the stored water is used up, whether that water came from a previous irrigation or from rain. Other growers still persist in the belief that a little moisture every day or every other day during a dry period is to be preferred. Some, at least, from this latter group can usually show a good crop on soil which seems to have a satisfactory moisture content. This practice, however, should tend to a shallow rooting system, unless the small amounts frequently supplied are enough to maintain suitable moisture in the natural root zone of the crops. Natural rooting will then probably develop, but deep rooting will not be induced. If pump or engine should fail so that further water could not be supplied after a crop had been started by the shallow but frequent water scheme, it is not known whether the crop would be worse off than similarly located crops irrigated more thoroughly but at less frequent intervals. Fortunately pump and engine failures seldom occur.

Friendly controversy still persists as to the time of day to irrigate. Some growers insist that irrigation with spray equipment should be done only at night, on cloudy days, or in the late afternoon. Most irrigators pay little or no attention to the time of day to irrigate. With large spray-irrigation installations, irrigating at only selected hours is impossible. No obviously harmful results come to most crops from disregard of the time of day.

If one is equipped with a furrow system that has a capacity to give a thorough irrigation to the entire tract in a 5-, 6-, 7-, or possibly 10-day period, it is generally desirable to start irrigating a little before the ground gets dry. It is important to remember that at best it will be possible to cover only a small part of the area in a day, and, therefore, if drought conditions are really setting in, the part of the field that is to be irrigated last will be pretty well dried out before the water gets to it.

CHOICE OF EQUIPMENT

The equipment for irrigating a certain tract deserves careful consideration if a wise choice is to be made. It may be desirable to investigate several complete systems before the final choice is made. Ultimate low cost will generally be the deciding factor, although occasionally other considerations outweigh it; such as, for instance, installing at somewhat greater expense in a time of depression a system of irrigation that requires little labor to operate with the hope of reducing operating costs in subsequent years when higher wages may prevail.

Table 12 may be taken as a more or less practical guide to current practice. The table covers a wide range, and while it is believed to be generally accurate, there are special cases where irrigation methods other than those outlined are suitable. Before any irrigation system is installed the suitability and quantity control should be questioned, as is indicated in the footnote. For instance, if the slope is greater than 5 percent (5 feet in 100), will the sprinklers deliver the water faster than the soil can absorb it? If the slope is a uniform one of approximately 3 percent, should a conveyor hose be used where a shallow ditch might serve? If it seems desirable to use surface irrigation on clayey soil with a sandy subsoil, can heavy losses of water from supply ditches into the sandy subsoil be avoided?

A topographic map of the tract to be irrigated is very desirable, but lacking that, the locations of the water supply, pump, and pipe lines or ditches may be shown on a good sketch drawn to scale. From this the length of various pipe lines may be determined as well as the number of strips or blocks that may be irrigated at one time.

In an effort to make certain details more clear to those who do not have nearby irrigation outfits that they may examine, sketches showing different arrangements for irrigating a 10-acre tract are shown (figs. 37–42). Although a number of arrangements and size groupings are possible, only a few can be shown.

The tract under consideration is 660 feet on a side with space reserved for a 14-foot road along three of the sides. This gives a net area of 9.37 acres available for cropping.

TABLE 12.—*Methods of irrigation suitable to various kinds of relief and soil*

Relief	Soil					
	Light-textured (sandy)		Medium-textured (silty)		Heavy-textured (clayey)	
	Pervious subsoil	Impervious subsoil	Pervious subsoil	Impervious subsoil	Pervious subsoil	Impervious subsoil
Level	Sprinkling, porous hose, conveyor pipe, conveyor hose.	Sprinkling, porous hose, conveyor pipe, conveyor hose, surface,[1] subirrigation.	Sprinkling, porous hose, conveyor pipe, conveyor hose, surface.	Sprinkling, porous hose, conveyor pipe, conveyor hose, surface,[1] subirrigation.	Sprinkling, conveyor pipe, conveyor hose, surface.	Sprinkling, conveyor pipe, conveyor hose, surface,[1] subirrigation.
Uniform slope, not over 1 percent.	Sprinkling, porous hose, conveyor pipe, conveyor hose, surface.	Sprinkling, porous hose, conveyor pipe, conveyor hose, surface, subirrigation.	Sprinkling, porous hose, conveyor pipe, conveyor hose, surface.[1]	Sprinkling, surface, subirrigation.	Sprinkling, surface [1]	Sprinkling, surface.
Gently rolling, ridges not over 1½ feet above nearby low spots.	Sprinkling, porous hose, conveyor pipe, conveyor hose.	Sprinkling, porous hose, conveyor pipe, conveyor hose.	Sprinkling, porous hose, conveyor pipe, conveyor hose.	Sprinkling, porous hose, conveyor pipe, conveyor hose.	Sprinkling, conveyor pipe, conveyor hose.	Sprinkling, conveyor pipe, conveyor hose.
Uniform slope, 1 to 5 percent.	Sprinkling, porous hose, conveyor pipe, conveyor hose, surface.[1]	Sprinkling, porous hose,[1] conveyor pipe, conveyor hose, surface,[1] subirrigation.[1]	Sprinkling, porous hose,[1] conveyor pipe, conveyor hose.	Sprinkling, surface, subirrigation.[1]	Sprinkling, conveyor pipe,[1] conveyor hose,[1] surface.[1]	Sprinkling, surface.
Rolling ridges, 1½ to 5 feet above nearby low spots.	Sprinkling, conveyor pipe, conveyor hose.	Sprinkling, conveyor pipe, conveyor hose.	Sprinkling, conveyor pipe, conveyor hose.	Sprinkling, conveyor pipe, conveyor hose.	Sprinkling, conveyor pipe, conveyor hose.	Sprinkling, conveyor pipe, conveyor hose.
Uniform slope, over 5 percent.	Sprinkling [1]	Sprinkling [1]	Sprinkling,[1] surface [1]	Sprinkling,[1] surface [1]	Sprinkling,[1] surface [1]	Sprinkling,[1] surface.[1]

[1] Special attention to suitability or quantity control should be given before installing.

It is assumed that the tract has a 6-inch cased well, near its center, as shown in figures 37 to 42, and that according to the well-test data draw-down distances are as follows: 3 feet when 60 g. p. m. is being pumped from the well; 4 feet for 80 g. p. m.; 5.2 feet for 100 g. p. m.; 6.4 feet for 120 g. p. m., and 7.7 feet for 140 g. p. m. The standing water level in the well is 10 feet down when the pump is not running. From the above data the operating water level may be determined although in doing so it may be convenient to plot well-test curve as shown in Farmers' Bulletin 1404, Pumping from Wells for Irrigation. The information indicates that a centrifugal pump should be set in a pit if more than 80 g. p. m. is to be withdrawn. No pit is needed for a displacement pump, even if pumping 140 g. p. m.

It is assumed that, as shown by the contours, surface irrigation may be readily used. It is further assumed that the tract is unusual in that it has a porous topsoil underlain at a suitable depth by an impervious stratum so that subirrigation may be used if desired.

The various plans follow, with special notes on each.

Using portable laterals and a portable main (fig. 37), tract to be covered 1 inch deep in seven 10-hour days, or 4,200 minutes. G. p. m. required $=\frac{9.37\times 27{,}152}{4{,}200}=60.5$.

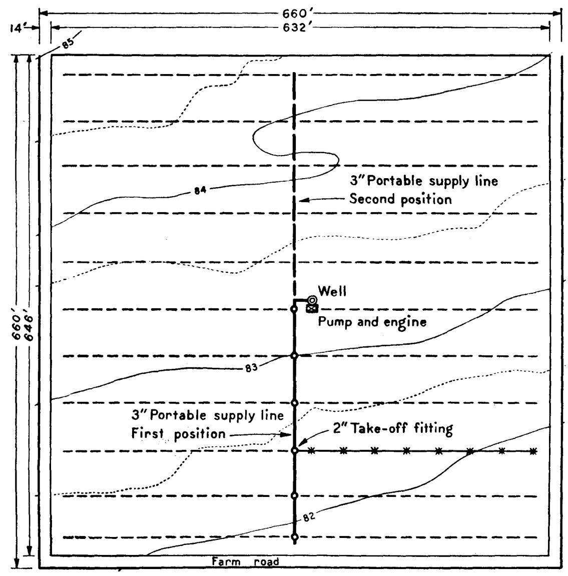

FIGURE 37.—Plan of a sprinkling system for a 10-acre tract using portable laterals and a portable main.

From a sprinkler-unit basis, allowing for sprinklers 40 feet apart along the portable sprinkler pipe and using eight sprinklers that discharge 7½ g. p. m. each under a pressure of 35 pounds per square inch, something more than 8×7½=60 g. p. m. will be required, owing to the higher pressure near the pump. The actual estimated requirement is 61.4 g. p. m., which will be enough to irrigate the tract in seven 10-hour days. A centrifugal pump capable of delivering 61 g. p. m. against a total dynamic head of 98 feet at its point of maximum efficiency would be well suited to this job. Probably a 5-horsepower engine or a 3-horsepower electric motor would be best suited to this installation.

Using portable laterals and a permanent main (fig. 38), tract to be covered 1 inch deep in six 10-hour days, or 3,600 minutes. G. p. m. required $= \frac{9.37 \times 27{,}152}{3{,}600} = 71$ from area basis.

From a sprinkler-unit basis, allowing sprinklers 40 feet apart along the portable sprinkler pipes and using eight sprinklers that discharge 15 g. p. m. under 40 pounds pressure, and operating on that basis, the g. p. m. required will be $8 \times 15 = 120$, as the friction loss in this case is negligible. Since this quantity of water has to be used to supply properly the irrigation equipment, each irrigation will be applied in approximately three and one-half 10-hour days instead of six 10-hour days.

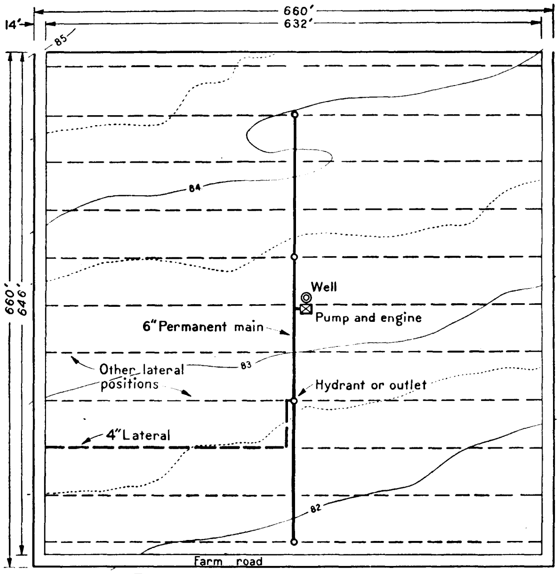

FIGURE 38.—Plan of sprinkling system for a 10-acre tract using portable laterals and permanent main.

A centrifugal pump capable of delivering 120 g. p. m. against a total dynamic head of 110 feet at its point of maximum efficiency would be well suited to this job. Probably a 7½-horsepower electric motor would drive this outfit satisfactorily, but for internal-combustion engine drive, either gasoline or Diesel, a 10-horsepower unit should be provided.

Using overhead-pipe system of sprinkling irrigation (fig. 39), tract to be covered 1 inch deep in three 10-hour days, or 1,800 minutes. G. p. m. $= \frac{9.37 \times 27{,}152}{1{,}800} = 142$.

Selecting nozzles to discharge 25 g. p. m. per lateral sprinkler pipe at 35 pounds pressure can operate six such nozzle lines simultaneously. Water thus required $= 150$ g. p. m. and indicated draw-down at well $= 8.4$ feet.

For this installation a centrifugal pump that reaches its maximum efficiency when discharging 150 g. p. m. against a total dynamic head of 120 feet is well suited to the work. Because of the height of the suction lift the pump should be set in a pit. To drive this pump a 10-horsepower motor would probably serve, but a gasoline engine should be the next larger commercial size, say 12-horsepower.

If the tract were to be covered 1 inch deep in six 10-hour days, as would be satisfactory for most growers, a 5-horsepower engine or

motor with the same pipe sizes but with only three laterals operating at a time could be used. A centrifugal pump with a capacity of 75 g. p. m. against 105 feet of head at maximum efficiency would then fit in.

For this same field, if covering the tract in seven 10-hour days would do, by using the same sprinkler and pipe sizes as considered in figure 37—nozzles that discharge 7½ g. p. m. under 35 pounds pressure, a 3-inch permanent main pipe and 2-inch portable laterals—a 5-horsepower gasoline engine or a 3-horsepower electric motor could be used to drive the pump.

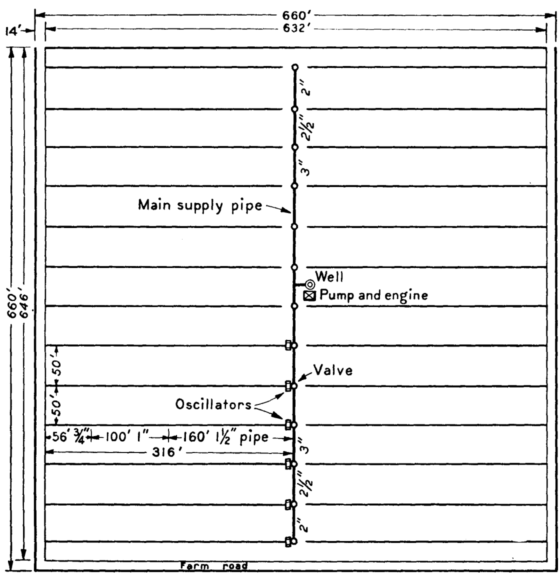

FIGURE 39.—Plan of overhead-pipe system of sprinkling irrigation for a 10-acre tract.

Using furrow irrigation (fig. 40), tract to be covered 3 inches deep in six 10-hour days, or 3,600 minutes. G. p. m. required $=\frac{3\times 9.37\times 27{,}152}{3{,}600}=212$.

The limited capacity of the well apparently precludes operation on this basis. Suppose, however, the requirement be reduced to covering the tract in ten 10-hour days or six 16⅔-hour days=6,000 minutes. For furrow irrigation according to this plan a small amount of grading as shown in figure 40 is necessary. G. p. m. required $=\frac{763{,}242}{6{,}000}=127.2$, which can apparently be withdrawn from the well with a draw-down of 7.0 feet, making a total lift of 17 feet to the ground surface when the pump is running.

A centrifugal pump that had its maximum efficiency when delivering 128 g. p. m. against a total dynamic head of 23.5 feet would be suitable for this job. It would deliver more than 128 g. p. m. to the central outlet near the pump, from which one-half of the area is irrigated, and considerably less after being transported, through a 4-inch steel-pipe main, to the most distant outlet, from which one-eighth of the area is irrigated.

A 2-horsepower motor or a 2½-horsepower engine could be used on this installation if a reasonably efficient pump were secured and a gate valve installed in the discharge pipe close to the pump. The purpose of this valve would be to prevent overloading of the driving outfit when

delivering water from the central outlet near the pump. Owing to the small size of the outfit, some overpowering is desirable. Unless a fairly efficient pump was obtained, many growers would prefer to use, and in all probability would secure greater all-around satisfaction by using a somewhat larger engine or motor.

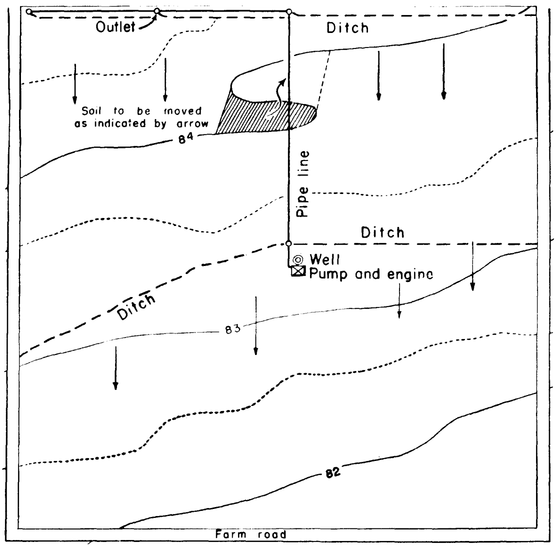

FIGURE 40.—Plan of furrow irrigation for 10-acre tract.

A 4-inch sewer-pipe main instead of a 4-inch steel-pipe main could be used with this outfit. Owing to the slightly greater carrying capacity of sewer pipe the friction when carrying 128 g. p. m. would be 1.62 feet per 100—somewhat less than in the previous plan—and the maximum head that could come on the pipe, allowing for 2 feet difference in elevation between the ground surface at the well and the elevation of the most distant outlet and also allowing for the center of the pipe to be 2 feet in the ground, still makes it possible to keep the maximum pressure on the sewer pipe from exceeding the 15-foot limit recommended. The engine horsepower is slightly reduced. A gate valve should be installed in the discharge pipe near the pump if a 2-horsepower engine or motor is used to drive the pump.

Or, a 3-inch steel-pipe main could be used instead of the 4-inch one. The friction factor would be higher—7.88 feet per 100 feet of pipe with 128 g. p. m. flowing. A centrifugal pump operating at maximum efficiency when discharging 128 gallons against a total dynamic head of 36 feet would be reasonably well suited to the job. Although 128 g. p. m. would not be delivered at the high outlet, there would be an adjustment of quantity and frictional resistance that would result in a reasonable quantity being delivered. Partly closing the gate valve at the pump when delivering from the central outlet right by the well might be necessary to keep from overloading the engine or motor.

The approximate horsepower requirement indicates that a 3-horsepower engine or motor would serve on this job if the machinery were kept in first-class condition; a 5-horsepower one would be preferred by many operators.

The high friction head precludes the use of 3-inch sewer pipe except for a short distance at the far end of the main.

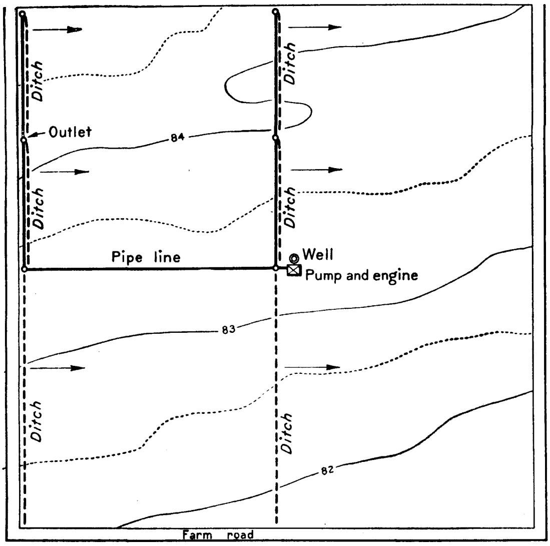

FIGURE 41.—Alternative plan for furrow system of irrigation for a 10-acre tract if only row crops in well-ridged rows are to be grown.

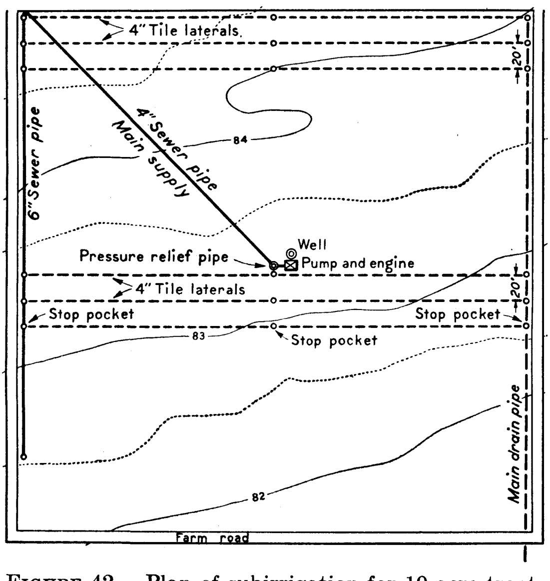

FIGURE 42.—Plan of subirrigation for 10-acre tract.

Figure 41 shows an arrangement of pipe lines and ditches for furrow irrigation that is to be preferred to the plan shown in figure 40 if the tract is to be used for crops grown in well-ridged rows. This plan requires no grading but the rows must be ridged enough to keep the water from breaking out sideways and running across, as the steepest slope is to the side. In some soils, if suited to 630-foot furrows, the central pipe line and ditch would not be required.

Engine and pump requirements are to all practical purposes the same as for those of the plan shown in figure 40, although if the central pipe line were necessary the average head against which the pump must work would be slightly greater in this plan if the time of operation at each outlet were considered.

Tract to be irrigated 6 inches deep in six 24-hour days by subirrigation (fig. 42).

This long day is chosen because little attention is needed under good subirrigation conditions and because the review of the water supply under the furrow-irrigation plan shows that water cannot be taken from the well with sufficient rapidity to cover the tract to a depth of 6 inches in six 10-hour days. The characteristics of the tract under subirrigation are not known, other than that the plot is suitable for that type of irrigation, and it is probably best to assume that it may take 6 inches depth per week to irrigate. If experience proves that a lesser depth

of irrigation is sufficient, the installation can be extended at a later date. Assuming that 140 g. p. m. (the maximum test quantity) is drawn from the well, the system can handle 7.41 acres in six 24-hour days, or 511 feet down a tract 632 feet wide.

A 4-inch sewer-pipe line could be taken directly from the pump to the high corner of the field and there connected to the 6-inch main supply line, also of sewer pipe, leading to the higher ends of the 4-inch tile lateral distributors spaced at 20-foot intervals. Although a 4-inch supply pipe will serve from the pump to the high corner of the tract, owing to the slight pressure available from the pump, a 6-inch pipe is required to handle the water by gravity under the slight slope down the side of the tract.

A 3-horsepower engine or motor would be required for this irrigation as outlined. As 24-hour operation of the pumping unit is contemplated here, safeguards against damage to the machinery should be provided, particularly arrangements for stopping the outfit if the pump should lose its priming. Overload and no-voltage protection should be provided for an electric unit, and a throttling governor for a gasoline engine.

INFORMATION NEEDED IN DESIGNING A PLANT

The United States Department of Agriculture receives many letters asking for information and suggestions regarding proposed irrigation projects in the humid region. The Department stands ready to offer such information, but before helpful advice can be given, the following necessary data must be furnished:

Acreage to be irrigated.

Kind of surface soil and subsoil.

Source of water supply; estimated quantity available. (If a well, the size and type of well, distance to water, and probable draw-down when pumped.)

Distance from water supply to land to be irrigated.

Difference in elevation between water supply and land to be irrigated.

Crops to be irrigated.

The general slopes of the land to be watered.

A sketch showing slopes of the land to be irrigated, location of the water supply, etc. It will be sufficient if this map indicates directions of slope by arrows and amount of slope in inches per 100 feet. An accurate topographic map is, however, very helpful and may be a means of saving money.

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